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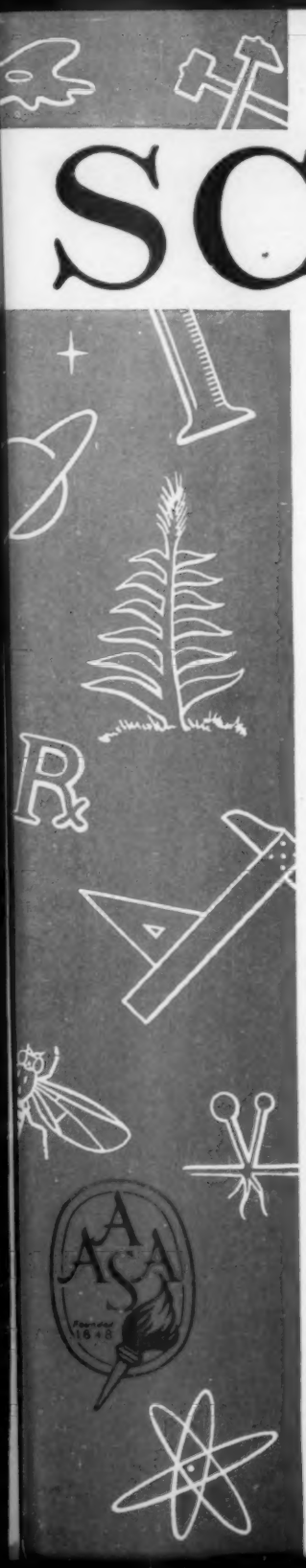

SCIENCE

OCTOBER 23, 1953

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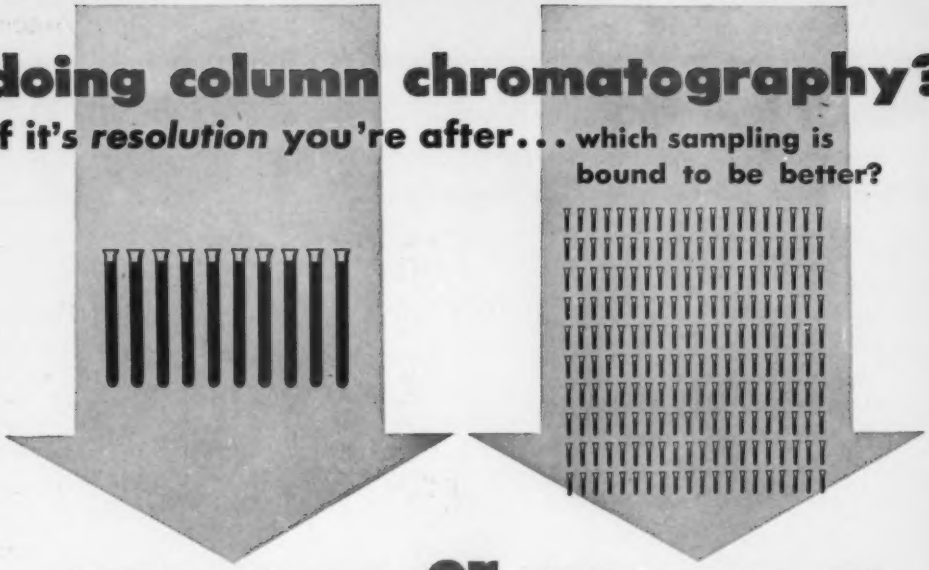

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The Instrument and the Spirit

THE instrument is the extension of the senses of the scientific investigator and the refinement and enlargement of his crude powers of manipulation. It renders precise his variable and subjective observations, and records in full and permanent form what would perish if it depended upon his memory and his notes. It has often been said that the history of modern science can be read in the invention and improvement of scientific instruments. For this reason alone it is important for us, at least once a year, to give a special place in the pages of SCIENCE to the advances being made in instrumentation.

Leonardo da Vinci, four and a half centuries ago, well knew the significance of new instruments and implements, and turned his giant talents, from painting the fresco of the Last Supper in the chapel of Santa Maria delle Grazie, to invention and engineering. Was art then simply to be a handmaiden of the sciences? Not at all, for what Leonardo sought in the sciences—in his studies of flowers, of the anatomy of the human heart, of the nature of fossils—was what he sought also in his experiments in painting, so often unsuccessful and uncompleted. The quest of Leonardo was the quest of the scientific spirit "to explore and to understand the universe . . . to grasp the forms and laws of nature and life as they revealed themselves to his alert and penetrating eye." Art thus became the effort to express in spirit the full scope of human knowledge and understanding. That effort by Leonardo to fuse science and art we recognize today as having been the supreme achievement of the Renaissance.

The role of the instrument in furthering this synthesis of which Leonardo dreamed has grown beyond even the bounds of his imaginative genius. Like thousands of other scientists, I can sit in my room before a few instruments, and have the world before me to see and to hear. Like so many other scientists, I find a special pleasure and refreshment in that synthesis of mathematical proportions, rhythms and harmonies with the creative imagination of the artist to make what we call music. To how many of us, then, the greatest triumph of the instrument is represented by the enlargement of the spirit it brings. The radioed word that death has so untimely claimed Kathleen Ferrier, whom we have never seen or heard in person, creates in us a bitter sense of personal loss. Yet the instrument conquers time as well as space and recreates anew at our will the full marvel of her voice and her artistry. Through the pickups, wires, condensers, electronic tubes, and metal diaphragms of our instruments we learn more fully the meaning, so pregnant for these uneasy times, of the words of John Donne:

> No man is an Iland, intire of itselfe; every Man is a peece of the Continent, a part of the maine; if a Clod be washed away by the Sea, Europe is the lesse, as well as if a Mannor of thy friends or of thine owne were; any man's death diminishes me, because I am involved in Mankinde; And therefore never send to know for whome the bell tolls; It tolls for thee.

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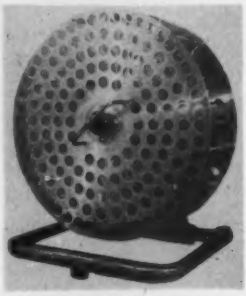

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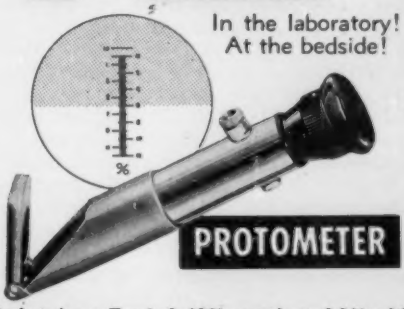

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Seventy-Five Years of Research in General Electric

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ONE OF THE OUTSTANDING FEATURES in the development of American industry has been the utilization of science and the application of scientific methods to the development of technologies. The total number of scientists in industry and the rate at which their numbers are increasing, together with the great growth of industrial research facilities, present striking assurances of our industrial strength and vitality. The application of science is undoubtedly a keystone in the development of modern industrial technology. It is a part and parcel of all its corollaries, including the great and increasing productivity of the American workman, the enhanced standard of living of our people, and the extensive use of labor-saving devices, even in the home.

It must be admitted that not all segments of American industry have been equally alert in utilizing the advantages of science, but the electrical, along with the chemical and aircraft industries, have been among the foremost in this regard. This is well exemplified by the history of the General Electric Company, now celebrating the seventy-fifth anniversary of the founding of its earliest component, the Edison Electric Light Company.

This company grew out of the scientific studies of Thomas A. Edison, who had established his laboratory in a long, white building at Menlo Park, New Jersey, in 1876. Arc lights were then coming into wide use, particularly for outdoor illumination, but indoor use required a smaller lamp, and there was much discussion of the problem of "subdividing the electric light."

Edison had some ideas as to how it might be done with an incandescent filament sealed in an evacuated bulb. On October 15, 1878, the Edison Electric Light Company was incorporated, and Edison was provided with ample funds for his researches. Hundreds of experiments took place during the next year. Finally, on October 19, 1879, Edison placed a carbonized cotton thread, bent into hairpin shape, inside one of his glass bulbs. The air was exhausted and the current was switched on; light came from the glowing thread. It burned for forty hours. Edison realized that success had come at last, for if the thread burned forty hours, it could be made to burn a hundred, or a thousand.

Thus the electric lamp was born. In the next few years it came into wider and wider use. The establishment of Edison's Pearl Street Station in 1882 in New York, inaugurated the era of electrical service supplied from a central station.

FIG. 1. Thomas A. Edison shown in the Menlo Park Laboratory with his first successful electric lamp, on October 19, 1879. (From a painting by Dean Cornwell.)

Meanwhile, at the Philadelphia Central High School, a young chemistry professor, Elihu Thomson, with the aid of a colleague, Edwin J. Houston, had invented a dynamo and other electrical devices. To exploit these, the American Electric Company had been organized in New Britain, Connecticut, whence Thomson had moved. In 1883 this firm was bought by a syndicate under Charles A. Coffin, a Massachusetts shoe manufacturer, was reorganized as the Thomson-Houston Company, and was moved to Lynn, Massachusetts. Nine years later, under Coffin's leadership, this company merged with the Edison General Electric Company, and the General Electric Company was the offspring.

Thus, even when the company was organized, it already had a distinguished technical background, with Edison on one side and Thomson on the other. In that same year another name destined for fame was added to the rolls—that of Charles Proteus Steinmetz. A German immigrant, possessed of a brilliant mind, he had arrived in New York in 1889 and had gone to work for Eickemeyer and Osterheld in Yonkers. There he developed the mathematics of the law of hysteresis, which governs losses in the magnetic circuit of an electric motor. This gave electrical engineers a powerful tool for designing efficient electric equipment. Mainly to secure Steinmetz' services, the Eickemeyer firm was purchased by General Electric in the summer of 1892. At first Steinmetz was employed in the calculating department at Lynn, but in 1894 this department was

expanded and moved to Schenectady, with Steinmetz heading it as Head Engineer for the Company. Here he did important work on the mathematics of alternating current, which had shown its advantages and was then coming into extensive use. Later he also taught at Union College.

Professor Thomson had his personal laboratory at Lynn, but the first formal Company laboratory was established at Schenectady in 1895, for "standardizing" work, which meant simply the cleaning, repairing, and calibration of electrical measuring instruments. A special building was erected for this Standardizing Laboratory, with copper nails and brass radiators, to insure freedom from the effects of unknown magnetic fields. This was the forerunner of the General Engineering Laboratory, which now performs an important function in helping apply to everyday life the new facts brought out by scientific research. Much of its activity relates to instruments, measuring devices, and other equipment used by scientists and engineers. Its guiding motto has been the famous words of Lord Kelvin: "When you cannot measure it, when you cannot express it in numbers . . . you have scarcely, in your thoughts, advanced to the stage of Science, whatever the matter may be."

Under its skilled engineering leadership, the new company advanced rapidly, but by the turn of the century it became apparent to several of its officials that something was lacking. Since engineering depends upon applied science, it is evident that scientific knowledge is the most important raw material of engineering development. Research, in turn, is the source of scientific knowledge. The electrical industry in 1900 was based on research that had been done a half century earlier by such men as Alessandro Volta, Joseph Henry, and Michael Faraday. Without a continuing supply of new scientific facts as a product of research, it was recognized that future engineering development would be impossible.

The leaders of the Company felt the need to participate in the fundamental research on which the industry was based. Why should not General Electric itself engage in fundamental research and so contribute to this source of its most essential raw material for future growth? Who first thought of this is still uncertain—the idea seems to have come simultaneously to E. W. Rice, vice president and technical director of the Company, Professor Thomson, Dr. Steinmetz, and Albert G. Davis, who headed the Company's patent department.

One day in the fall of 1900 Steinmetz and Davis entered Rice's office. "Mr. Steinmetz and I," said Davis, "believe it would be an excellent idea to create a laboratory where scientific investigations might go forward on the incandescent lamp and other problems. We should like to recommend such a step for your serious consideration."

"To improve electric lighting is our foremost thought," he went on. "I personally feel, and Mr. Steinmetz endorses my views, that the electric light has a future more brilliant than its past. We should not like to assert that the carbon-filament lamp is the best lamp we can have. There may be a better type of electrode for arc lamps than the carbon electrode. These things cannot be determined properly without research."

FIG. 2. When the General Electric Research Laboratory was organized in 1900 it was housed in this barn at the rear of the home of Dr. C. P. Steinmetz in Schenectady.

Since Rice had already been thinking along similar lines, the idea fell on fertile ground. They agreed to establish such a laboratory, entirely divorced from the factory and sales organization, where the guiding principle would be that of adding to fundamental knowledge. As director of the new undertaking they selected Dr. Willis R. Whitney, a young chemistry professor at the Massachusetts Institute of Technology, whom Thomson had met and admired.

The first home of the laboratory was a barn back of Steinmetz' home; the second, a building in the General Electric Schenectady Works which had been vacated by the Standardizing Laboratory when it moved to larger quarters. Next came another converted factory building, and in 1914 the Research Laboratory moved into a building erected especially for its

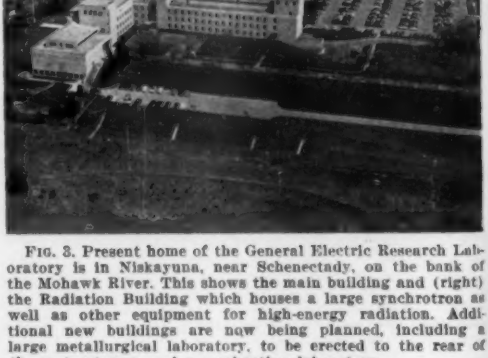

FIG. 3. Present home of the General Electric Research Laboratory is in Niskayuna, near Schenectady, on the bank of the Mohawk River. This shows the main building and (right) the Radiation Building which houses a large synchrotron as well as other equipment for high-energy radiation. Additional new buildings are now being planned, including a large metallurgical laboratory, to be erected to the rear of the water tower, and a combustion laboratory.

needs. Eleven years later another building, connected with the older structure by a bridge, was added; but, at the end of World War II, even these were inadequate. The Research Laboratory moved to its new quarters on a 260-acre site at the Knolls, outside Schenectady, which was dedicated in October, 1950, at the time of the Laboratory's fiftieth anniversary.

From the start, electric lighting engaged the attention of a large section of the laboratory, and indeed it still does. One of Whitney's first developments was the metallized carbon filament, utilized in the Gem lamp, introduced in 1905, which gave a 25 per cent higher efficiency than its predecessor and had the same life. But this lamp was soon superseded by the tungsten lamp. Filaments for this were first made by a process developed in Europe whereby a tungsten powder in paste form was squirted through a die to form a thread. This thread was then heated to drive out the binder and make the metal particles cohere in a filament. Even though such filaments were very fragile, their superiority in producing light led to the manufacture and use of tungsten lamps in large numbers.

In that same year of 1905 Whitney had induced another chemist at the Massachusetts Institute of Technology, Dr. William D. Coolidge, to join his staff. Coolidge also became interested in the lamp problem and soon made a considerable improvement in the process of making squirted filaments. But by 1908 he had developed a process of making tungsten ductile. Since the metal could then be drawn into a wire, the modern tungsten lamp, able to withstand rough treatment, was developed and made its appearance in 1910.

Dr. Irving Langmuir, who had come to the laboratory from the Stevens Institute of Technology in 1909 to spend the summer vacation—and remained—made the next important improvement in lamps. At that time it was supposed that a better vacuum was necessary to make a better lamp. To learn whether this might be a hopeful approach, Langmuir set out to find the basic effects of a number of different gases in experimental lamps at various degrees of vacuum.

Eventually this showed that a better vacuum was not needed, but that a higher efficiency could be secured with an inert gas, such as nitrogen, inside the bulb, provided the filament was properly designed. The original gas-filled lamp, introduced in 1913, was about twice as efficient as the vacuum lamp, and since then additional improvements have increased its efficiency.

Langmuir's work on heat losses from hot filaments also led to the atomic-hydrogen welding torch. In this device a stream of hydrogen is passed through an electric arc between two tungsten electrodes, and the hydrogen molecules are dissociated into atoms. However, as the atoms leave the arc they recombine, producing a flame far hotter than ordinary welding flames. In addition to the high temperature, there is the further advantage that the nitrogen, as well as the oxygen, of the air is kept away from the weld by the cloud of hydrogen around it. This prevents the formation of nitrides, which would weaken the weld. Atomic-hydrogen welding made possible for the first time the easy welding of aluminum, chromium, and other previously unweldable metals.

FIG. 4. Sir J. J. Thomson (center) examined a new type of electron tube when he visited the General Electric Research Laboratory in 1923. He is shown here with Dr. Irving Langmuir (left) and Dr. William D. Coolidge.

After Coolidge had developed ductile tungsten, he looked for other uses for the novel material and found that it made an excellent target for x-ray tubes. But even with a tungsten target, x-ray tubes of that period were erratic affairs, since the electron emission from the cold aluminum cathode depended on a complex process involving the small amount of residual gas remaining in the tube. In the Coolidge x-ray tube, introduced in 1913, electrons are emitted from a heated tungsten filament and are accelerated toward the target by a high voltage. With the need for residual gas eliminated, the tube could be evacuated to a high vacuum. Before many years had passed, the reliability and ease of control of the Coolidge tube had led to its replacing the cold-cathode tube in nearly all applications.

At about this time, Langmuir was working on another problem involving electrons and gas in tubes. De Forest's audion, the original three-element electron tube, had recently been introduced and was used as a detector for radio signals and as an amplifier, and also in an oscillator in the transmitter. Its use as a transmitting tube, however, was severely limited, since its power output was low. Like the pre-Coolidge x-ray tube, it also would not function without a small amount of residual gas.

Langmuir discovered what limited the power of the audion. Even with the highest attainable vacuum, elec-

trons were emitted from the hot filament, but they tended to accumulate around it in a cloud. Thus they formed a "space charge," which repelled additional electrons seeking to leave the filament. If some gas was present, enough electrons were utilized in producing ionization so that the space charge did not form. Langmuir found it possible to use a high vacuum if the parts of the tube were quite close together, so that the electrons did not have far to travel. Using extra-high voltage to pull them across the intervening space, the effect of space charge could be eliminated and the tubes operated at high power. This made possible tubes operating at as much as 100,000 watts, or even more, which are used today in radio and industrial applications.

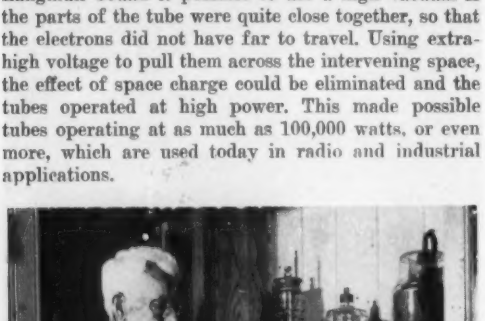

FIG. 5. Dr. Albert W. Hull, for many years assistant director of the General Electric Research Laboratory, with some of the electron tubes which he developed.

After these pioneer studies by Langmuir and Coolidge, electronics continued to occupy the attention of a large laboratory group. Dr. Albert W. Hull, who joined the staff in 1914, is credited with developing more types of electron tubes than any other man. One of his contributions was the thyratron, used in controlling heavy currents, such as those used in large industrial motors, or the lights in a large theater like Radio City Music Hall.

Another Hull invention was the original magnetron, a tube in which the variations in a magnetic field control the electrons, and hence the flow of current. With important modifications introduced later by scientists in several countries, the magnetron played an important role in radar as used in World War II and in peacetime radars now used by ships and airplanes. During the war, a laboratory group, under Hull, developed magnetrons to produce high-power waves at high frequency for jamming enemy radar. Tubes of this type are now employed to produce such waves for the heating of plastics and similar materials.

In the Laboratory's metallurgy division, a continuing research has resulted in improved iron for the magnetic circuits of electrical apparatus such as transformers. Operating on alternating current, these transformer cores become magnetized and demagnetized many times a second. Their properties, therefore, must be exactly opposite to those of permanent magnets, which should retain their magnetism despite surrounding effects. Transformer iron, therefore, must give up its magnetism as quickly as possible, otherwise energy is wasted. As a result of an extensive research program to find the factors that determine such magnetic losses in silicon steel, the iron alloy generally used for transformer cores, losses are now a third of what they were when these studies began.

At the same time that one group of Research Laboratory metallurgists were working on these problems, another group was engaged in the development of permanent magnets. The result was whole series of alloys, many of which are forms of Alnico, an alloy of iron, aluminum, nickel, and cobalt. Other metallurgical research has developed alloys able to withstand the extremely high temperatures encountered inside gas and steam turbines and jet engines.

Particularly significant is the work of a large group in our Metallurgy Research Department concerned with the fundamental properties of metals. Much of metallurgy in the past has been an empirical study—an art rather than a science—but now, unquestionably, a real revolution in the theory and practice of metals and alloys is taking place. In many important properties of metals, such as tensile strength, magnetic energy and high-temperature rupture strength, theoretical limits imposed by nature are vastly higher than practical values in present use. The properties of metals and alloys provide a limit to the performance and capability of a vast array of mechanical things, and hence there is a great premium upon improved metallic materials.

One of the most important of many chemical developments has had to do with the silicones. Although these had been discovered about 1870 and had been extensively studied in England, they were regarded as chemical curiosities, without practical value. They consist of long-chain molecules, with a backbone of alternate silicon and carbon atoms to which groups of hydrogen and carbon atoms are attached on the side. Their structure suggested that they would have high resistance to thermal effects. This was confirmed by studies in the Research Laboratory, which ultimately developed a new and simplified direct synthesis of the compounds. In addition to their use as electrical insulation in applications where high temperatures are encountered, silicones are used for making water-repellents, elastomers, which remain flexible at temperatures well above those at which ordinary rubber hardens, for synthetic oils, which flow easily at very low temperatures, yet do not decompose when hot, and for chemical- and heat-resistant finishes for metals.

As a direct outgrowth of Dr. Coolidge's early work on x-rays, a series of high-voltage x-ray units has been developed in recent years. It proved impracticable to operate a tube of the ordinary type at more than about

250,000 volts, but Coolidge applied a "cascade" principle for higher voltages. That is, instead of accelerating the electrons to the required energy in one stage, he used several stages, which made it possible to reach a million volts, or more.

The first units embodying these principles were made for various hospitals for cancer therapy. Later, a series of improvements made it possible to make them much more compact and mobile, and these were applied industrially for radiography of thick steel castings. Million-volt, and later two million-volt, units of this type are used in many industries, while similar principles have been applied to improved medical units as well.

In the last few years, one of these million-volt units, modified to let a beam of electrons emerge into the open air, has been used as a source of 900,000-volt cathode rays, which have been found to have interesting physical as well as chemical effects. For example, they may be used for sterilizing things like blood plasma and pharmaceuticals, without causing any significant increase in temperature. Also, by their aid, many new chemical reactions may be produced; the polymerization, depolymerization, and crosslinking of organics offer interesting possibilities, so that a whole new field of "electron chemistry" seems to be emerging from such work.

To go to even higher voltages, the betatron was developed, a task in which the Research Laboratory played an important role. In this device electrons are accelerated inside a toroidal vacuum tube in a fluctuating magnetic field. A 20-million-volt betatron, completed in 1941, was later loaned to the University of Illinois and was the prototype for a number of machines built for wartime applications. In 1943 a 100-million-volt betatron was completed and this has since been used extensively for nuclear research.

About 1945 a new type of accelerator, now known as the synchrotron, was proposed independently by E. M. McMillan, of the University of California, and V. I. Veksler, in Russia. A synchrotron yielding x-rays of 80,000,000 volts energy was completed in the Research Laboratory in 1947. This, the first in the United States, was sponsored by the Office of Naval Research. Another laboratory group, also originally supported by the ONR, has since built a synchrotron of novel type, with the coils of wire around a core of air, rather than of iron, as in its predecessors. This machine is capable of generating radiation of 300,000,000 volts energy.

In the late 1930's it was first realized that the fission of uranium might be a source of nuclear energy. It was in March, 1940, that two groups, the one composed of two Research Laboratory scientists, K. H. Kingdon and H. C. Pollock, and the other directed by A. O. Nier, at the University of Minnesota, simultaneously and independently made the first separation from natural uranium of U^{235}, which was thereby shown to be the isotope that underwent the fission reaction.

At the end of World War II an Atomic Power Division was organized within the Research Laboratory to study possible applications of atomic energy for peacetime uses. This later became the Knolls Atomic Power Laboratory, operated by the General Electric Company for the Atomic Energy Commission. Later, it was separated from the Research Laboratory and set up as an independent unit. Since 1950 its principal activity has been the construction of a nuclear reactor, utilizing neutrons of intermediate energy, to power a submarine for the U.S. Navy.

Probably the best-known research activity of the Laboratory in recent years has been its work in experimental meteorology. During the war, Dr. Irving Langmuir and his associate, Dr. Vincent J. Schaefer, worked on smoke and fog particles, devising the highly efficient smoke generator used to provide cover for landings in the South Pacific as well as for the crossing of the Rhine. They also worked on the causes of static produced in aircraft radio when flying through a snowstorm.

This work led Schaefer to try to discover how snow crystals were formed. In a home freezer, at a temperature of about −18 C, he formed a cloud of moisture. Although it was well below the ordinary freezing point, it consisted of supercooled water droplets, and various nuclei were introduced in an unsuccessful effort to change it to a cloud of ice crystals. Finally, on a hot day in the summer of 1946, he happened to drop into the box a large piece of dry-ice, to help get the desired low temperature. A cloud of ice crystals immediately formed. Schaefer, who had previously found that snow will form from a supercooled cloud spontaneously at −39 C, recognized that the dry-ice had cooled it below this critical temperature, thus forming millions of tiny ice crystals, which then acted as nuclei on which the rest of the moisture in the cloud could deposit.

On November 13, 1946, he dropped dry-ice from an airplane over a supercooled natural cloud and found that it turned to snow. Later, another General Electric scientist found that silver iodide could form nuclei that would produce similar effects, and other methods were also discovered. As a result of these discoveries, a weather research program known as Project Cirrus was set up in March, 1947. This was a joint study by the U.S. Army Signal Corps and the Office of Naval Research, in consultation with the Research Laboratory. Although Project Cirrus was terminated in May, 1952, much of the research has continued. It is not easy to predict the ultimate results, but it seems certain that the pioneering work of these General Electric scientists in cloud physics, cloud seeding, and weather modification will eventually have a profound influence on all of us. Rainmaking, which has been popularly identified with this project, is really only one aspect of the very broad subject of experimental meteorology.

In American industry there is a wide variation in what is considered research. Some research laboratories range all the way from fundamental studies of properties of matter through development to services for patent licensees. In our own company, from the

start, the Research Laboratory has had a primary interest in exploratory research. However, there is no sharp dividing line between this and applied research, and necessarily we do a great deal of the latter as well. There are more than a score of other laboratories in the Company, all doing important and necessary applied scientific work, since a new development, to be of the greatest value, has to be put into use, and there are usually many important practical problems to be solved after a new result of research leaves the Research Laboratory.

Our experience shows that the technological process frequently requires a great many distinct steps, which seldom can be negotiated by broad leaps and short cuts. Very infrequently does a research development go directly to manufacture and use. It seldom goes directly to the design engineering point in the technological chain.

The typical research result has great promise; because of one or two irritating features which are extremely minor in the eyes of the scientist, but which loom as major obstacles to the engineer, the new result cannot be of immediate use. This impasse is overcome by very skillful people engaged in what is variously termed development work, or engineering development, or advanced engineering. Whatever the name, the activity comprises the one or more important steps in technology that lie between research and design engineering. We have found that these development steps are practically indispensable to the success of the technological process.

Furthermore, this task is best accomplished by development scientists and engineers who have this important work as a primary responsibility. It is seldom done well by people who are supposed to do it in time left over from a more important assignment. Thus, the development step, preferably a separate laboratory, is a vital step in the technological process; to be most effective it must be given organizational identity and a clear responsibility for this work.

The widespread interests of the General Electric Company, in a great variety of fields, have made possible our varied research activities, since any one of many different developments may be of potential value to some operating division.

In a highly specialized industry, on the other hand, research must be specialized to fit the industry. For example, the manufacturer of a line of organic chemical products, which are highly specialized with respect to raw materials, manufacturing equipment, and markets, is happiest if the results of his research fit immediately into his present manufacturing and marketing capabilities without change, and of course at very much lower cost. Basically, the degree of freedom of the industrial research scientist is thus determined by the diversity of the industry in which he works.

If the research chemist, for example, can work only toward results that fit like a glove into the capabilities of a specialized industry, little room is left for the play of his originality, for following the byways of research in the investigation of the unexpected result, and for the exploration of the nearby area of a great, but speculative promise. Worse still, scientists of skill and imagination will not long work within a closely limited scope; if one must be certain of the results of research in advance, the objective must be of such short range that it hardly partakes of a research character. The net result is likely to be frustrating to the scientist and disappointing to the sponsor.

It is better to leave some room for originality and imagination, which are important attributes of creative individuals. Furthermore, a little diversity may do no harm to the industry and may provide a degree of stimulation that is reflected in old as well as new products.

Despite the great development in American industrial research since 1900, when the General Electric Research Laboratory was founded, there remain important areas where scientific research has not yet been fully established. Throughout the technical industries we still have much to learn about the most effective pursuit of research and development and its detailed problems. Still more important, however, is the fact that, by and large, industry is not sufficiently speculative in its research. We often control our research too closely and confine it so narrowly to existing product areas that it fails to develop its full potentialities for new results. In short, in a free enterprise system we could well afford to be a bit more enterprising in exploring the greatest frontier the world has ever known—the frontier of science.

Basic Instrumentation at the National Bureau of Standards

A PROGRAM of research and development in basic instrumentation is now in its fourth year at the National Bureau of Standards. Under the general direction of W. A. Wildhack, Chief of the NBS Office of Basic Instrumentation, new applications of physical principles are being evaluated and applied to problems in measurement and control. Theoretical analyses are also conducted in various phases of instrumentation, and critical surveys are made of available instruments and techniques for types of measurement that are becoming increasingly important.

The NBS Office of Basic Instrumentation was established in 1950 to serve as a research, reference, and consultation center on problems of instrumentation for the laboratories of government and industry. Its program is sponsored by the Office of Naval Research, the Air Research and Development Command, the Atomic Energy Commission, and the National Bureau of Standards. While this program constitutes only a relatively small part of NBS activities, it represents an effort to utilize the Bureau's facilities and experience in the field of physical measurements to advance those techniques of measurement and control that are fundamental to progress in science and industrial technology.

Improved instruments for measuring basic physical magnitudes are vital to advances in the physical sciences and their applications (*1–3*), yet until recently the problem of designing instruments to measure different quantities and for use under different conditions has been largely left to the individual scientist or engineer working in his particular technical field. However, it is coming to be more and more widely recognized that the problems met with in designing various kinds of scientific instruments have much in common and that the designer of an instrument for a specific purpose can often benefit from the experience gained by others with instruments built for quite unrelated purposes (*4*). In an effort to realize the advantages that would accrue from coordinated planning of research on instrumentation as a science in itself, the NBS Office of Basic Instrumentation was established. Under such a program, it has been possible to take advantage of ideas and developments originating in various technical fields that have a bearing on basic instrumentation problems.

The technical work of the Office of Basic Instrumentation has two principal objectives: (*a*) systematic analysis of available methods and devices in terms of their performance and characteristics and (*b*) research on new applications of principles and materials leading to the development of instruments and techniques not now available. This program is carried out largely through the assignment of instrumentation research projects to those NBS laboratories that are best qualified to conduct research in the particular field of science involved (*5*). However, the Office of Basic Instrumentation also maintains a small laboratory staff of its own for investigation of special problems and a group of specialists in instrumentation literature who are developing a reference and consultation service to aid in the solution of instrumentation problems.

The various projects included in the technical program may be classified into four groups:

1) Critical surveys of available instruments or techniques for certain types of measurement that are taking on increased importance.

2) Projects for the theoretical or experimental evaluation of new applications of physical principles to general problems in measurement and control. Normally such projects are limited to a basic exploration of probable fruitful applications and do not involve development of specific instruments incorporating such applications.

3) Projects for the new application of physical principles to specific problems in measurement and control.

4) Projects for theoretical analysis and development in various fields of measurement, control, or handling of measurement data.

In the earlier phases of the program, experimental projects of the types described under (2) and (3) predominated, largely because technical personnel particularly suited for a number of such projects were available. However, as the program proceeded, it has been possible to place additional emphasis on projects under (1) and (4). In particular, survey projects have been initiated in a number of important areas.

Surveys

The critical surveys of various general types of instruments are designed to assist the engineer or scientist in making the proper selection of existing types of instruments for new applications as they arise or to aid him in combining various elements of known characteristics in the design of new instruments. Such surveys also provide the information needed for adequate planning of more specific instrumentation projects. Surveys of this kind now in progress include studies of millimicrosecond oscillography, dynamic pressure instrumentation, strain-gage recorders, voltage-sensitive devices, and analog-to-digital converters.

Large fluctuations in fluid pressure, often occurring at high frequencies, present an important problem in the design and operation of jet aircraft, rockets, and chemical plants. Recent needs, particularly in aeronautic and ordnance research, for making dynamic fluid-pressure measurements have indicated the prac-

tical necessity of a survey in this field. It is believed that an up-to-date compilation of significant techniques will be of great value to all workers faced with such problems. Thus far a bibliography of about 250 books, articles, and reports of various government research laboratories, covering the period from 1920 to the present, has been assembled, and a broad outline has been prepared to guide an investigation of the literature. The present bibliography is to be extended, and individual articles are to be reviewed and summarized. The manufacturers' literature will also be reviewed, and some attempt will be made to evaluate instrument performance where data are available.

The survey of millimicrosecond oscillography has also progressed. Recent developments in radar, television, atomic physics, telemetering, and other fields have greatly increased the need for oscillographic measurements in the time range below one microsecond. As a result, newer and faster oscillographs are being developed. Such instruments will also find applications in the study of electrical breakdown under steeply rising voltage surges—a subject of growing importance in insulation testing. A survey in this field is expected to be useful not only in the planning of new research but also for guidance in instrumentation problems concerned with the recording of high-speed transient voltages.

Although analog-to-digital converters are used in a number of different applications and new types are being developed to meet new situations, the development and use of such devices has been hampered by the lack of a comprehensive picture of the requirements to be met and the techniques presently used to meet them. In an effort to bring widely scattered information on this subject together, data have been collected on analog-to-digital converters manufactured by commercial companies and on those now being developed by these companies and by government agencies.

The survey of strain recorders, recently undertaken, has as its object the gathering of technical information that will aid in the selection of equipment for producing autographic stress-strain records of tensile tests. The use of recorders for this purpose has become standard practice in most materials testing laboratories. However, the recorders are supplied by manufacturers in a variety of forms, and there is little in the open literature to guide the user in the selection of equipment. There is even less information regarding the accuracy of recorders and strain gages. The results of this survey will be based on laboratory studies at NBS as well as on information obtained from other sources.

Specific Problems

Laboratory studies of more specific problems in instrumentation have resulted in a number of developments having broad potentialities for measurement or control. For example, a method[1] was developed which uses heavy water to determine the total water content of biological tissues, proteins, inorganic crystals, and other materials. Based on a spectroscopic measurement of the ratio of ordinary to heavy water in a solution containing the sample, the isotopic method is outstanding in the rapidity and convenience with which it can be applied to a large number of samples.

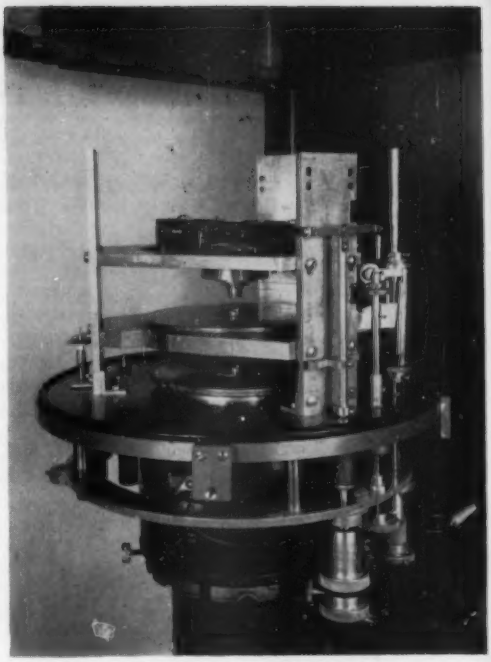

Fig. 1. Internal mechanisms of the NBS electron-beam interferometer. The interferometer employs diffraction from an extremely thin crystal as a means for splitting and recombining an electron beam and uses an electron optical system for viewing the resulting interference phenomena. Three crystals are mounted in an evacuated chamber that replaces the object chamber of an electron microscope. Each of three crystals are placed on mounts that may be rotated about the optical axis. The mount of the first crystal (top disk) may also be translated. The spacing between each crystal is 3.48 cm. Copper crystals approximately 100 A thick and about 3 mm in diameter are enclosed in small capsules that are placed in the center of the disk-like mounts. The controls for the crystal motion are brought to the outside of the chamber through vacuum-tight seals.

In another project of this kind, research on the wave properties of electrons has resulted in the development of an interferometer[2] that utilizes electron beams to produce interference fringes in much the same way as conventional optical interferometers use light beams. The NBS electron interferometer (Fig. 1) greatly extends the range of light interferometers used in the direct measurement of length. The instrument also constitutes an extremely sensitive device for measuring gradients of magnetic and electrostatic fields, analogous to refractive indices in optical interferometry,

[1] Isotopic method determines water content, *NBS Tech. News Bull.*, **36**, 145 (October, 1952).

[2] Electron-beam interferometer, *NBS Tech. News Bull.*, **37**, 101 (July, 1953); Electron interferometer, by L. Marton, *Phys. Rev.*, **85**, 1057 (1952).

and provides a means for obtaining additional information on the wave nature of the electron. Other suggested applications of the method include studies of the energy levels in solids and an absolute determination of Planck's constant.

Spurious electrical signals, or "noise voltages," present a problem in many types of instrumentation work where cables are subjected to mechanical shock and vibration. They interfere with measurements of pressure in underwater explosion and air-blast research and with determination of acceleration in shock and vibration studies. They also adversely affect the performance of crystal-type microphones, hearing aids, and phonograph pickups, and of many other high-impedance devices in the fields of communication, measurement, and control. The mechanism of the noise generation was not generally understood and was often assumed to be somehow related to piezoelectric or converse electrostrictive effects, changes in the electrical constants of the cable, or separation of electrical charges by friction. Last year a detailed theoretical explanation was formulated for the generation of the spurious signals, and a low-noise instrument cable[3] was developed.

FIG. 2. Critical flow hygrometer developed by the NBS Office of Basic Instrumentation. The device is based on the principles of gas flow at sonic velocity through orifices.

In connection with a program aimed at extending the range and accuracy of dynamic mechanical measurements, the NBS Office of Basic Instrumentation in 1951 developed a miniature piezoelectric accelerometer[4] for direct measurement of high-frequency vibrations. The device, which employed a barium titanate crystal as the compressive element, was extremely small but in many ways superior to other instruments used to measure mechanical vibration and shock. Further investigations of the barium titanate accelerometer, largely concerned with design characteristics and calibration methods, have continued. In the course of this work a model has been developed having exceptionally wide ranges of acceleration and frequency response (50,000 *g*, 100,000 cps).

[3] Noise-free instrument cable, *NBS Tech. News Bull.*, **36**, 37 (March, 1952).

[4] Miniature piezoelectric accelerometer, *NBS Tech. News Bull.*, **35**, 141 (October, 1951); A ceramic accelerometer of wide frequency range, by Lawrence T. Fleming, *Instruments*, **24**, 105 (1951).

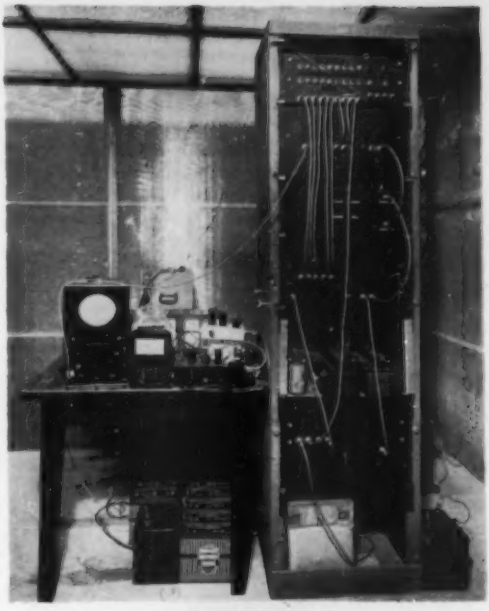

FIG. 3. The thermal noise thermometer, an instrument which determines temperature from the thermally generated electrical disturbance in an electronic circuit. Originally conceived and constructed at the University of Chicago, the noise thermometer has been redesigned by the Bureau in connection with its program in basic instrumentation. Amplifiers for the current from the temperature-sensitive element are at right. At left are a monitoring oscilloscope and an integrating circuit.

Research and development work on applications of pneumatic principles has resulted in a series or family of new instruments[5] based on gas flow at sonic velocity through nozzles. Utilization of these principles promises to provide improved instruments for the measurement of pressure, temperature, rate of flow, humidity, gas composition, mechanical displacement, and other quantities. A humidity measurement instrument has now been completed, providing a background of information that should be of value in the development of other instruments using the sonic flow principle (Fig. 2).

Other investigations of this kind that have been undertaken deal with such topics as the thermal noise thermometer, an electronic coating thickness gage, a carbon dioxide hypsometer, strain and displacement in-

[5] A versatile pneumatic instrument based on critical flow, by W. A. Wildhack, *Rev. Sci. Inst.*, **21**, 251 (1950).

struments, an ultrasonic velocimeter, feedback around image scanning systems, a phase sampling telemeter, the mutual inductance transducer, measurement of humidity by spectroscopic methods and microwave techniques, neutron spectrometer evaluation, and nucleonic instrumentation utilizing memory devices.

The carbon dioxide hypsometer represents an attempt to utilize the temperature of subliming solid carbon dioxide in equilibrium with its vapor at ambient pressure as a measure of pressure in upper air research. Several experimental models of this device have now been constructed and tested at pressures corresponding to altitudes up to 105,000 feet. The noise thermometer project was designed to evaluate the capabilities of the noise thermometer (Fig. 3), originally developed at the University of Chicago, as an instrument for measuring temperatures on the thermodynamic scale and to investigate the suitability of the device for other temperature measurement and control applications. The ultrasonic velocimeter is expected to provide a simple, accurate method for measuring the speed of sound in liquids. A model of the device is now being used by the Navy to measure the speed of sound in water at various depths. The electronic thickness gage is designed to nondestructively measure the thickness of metallic coatings which differ from the basis metal in electrical resistivity or in magnetic properties. The gage is capable of working with nonmagnetic metals in applications such as the measurement of the thickness of silver on brass. The phase sampling telemeter, which utilizes a commutator-type sampling device, has been proposed as a system that may offer improvements over present telemetering systems for certain applications in accuracy, reliability, complexity, weight and size of components, and power requirements. The project on strain and displacement instruments involves work on high-range and high-temperature types of strain gages as well as the design and construction of improved models of the Ramberg vacuum tube accelerometer,[6] originally developed by NBS in 1946 for acceleration measurements in aeronautical work (Fig. 4).

FIG. 4. The Ramberg vacuum tube accelerometer is essentially a double diode with elastically supported plates on either side of the common cathode.

[6] The improved Ramberg vacuum tube accelerometer, *NBS Tech. News Bull.*, **34**, 180 (December, 1950).

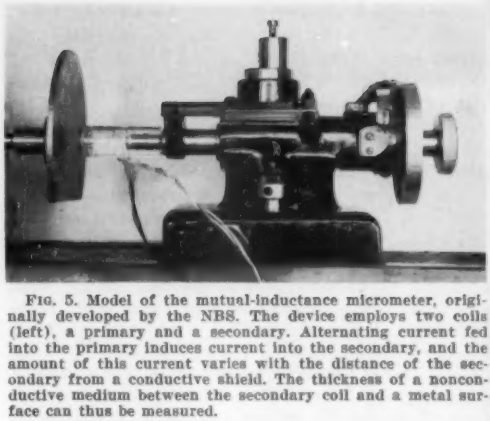

FIG. 5. Model of the mutual-inductance micrometer, originally developed by the NBS. The device employs two coils (left), a primary and a secondary. Alternating current fed into the primary induces current into the secondary, and the amount of this current varies with the distance of the secondary from a conductive shield. The thickness of a nonconductive medium between the secondary coil and a metal surface can thus be measured.

The work on image scanning systems is a study of the application of two-dimensional linear and nonlinear feedback in optical-electronic systems using cathode-ray tubes. Contributions to research may result from solutions of nonlinear partial differential equations by this technique. Practical results may also be derived from its use as an aid in the recognition of patterns, such as the matching of fingerprints, automatic reading of printed or written matter, or possibly in weather prediction from synoptic maps.

An investigation has been conducted to determine the characteristics of the mutual-inductance micrometer,[7] originally developed by NBS in 1947, as a transducer for various applications (Figs. 5 and 6). An effort has been made to determine the influence of a large number of factors on the performance of a mutual-inductance transducer so that the optimum design for any specific use can readily be chosen.

In 1950 NBS developed a recording microwave refractometer[8] of high sensitivity that can continuously sample and record the dielectric constant of a stream of air or other gas. This instrument is now being investigated to determine its potentialities for use as a

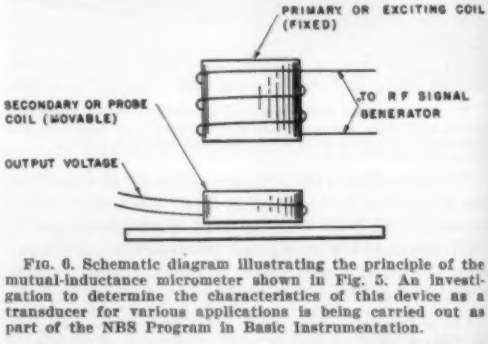

FIG. 6. Schematic diagram illustrating the principle of the mutual-inductance micrometer shown in Fig. 5. An investigation to determine the characteristics of this device as a transducer for various applications is being carried out as part of the NBS Program in Basic Instrumentation.

[7] Electronic micrometer, *NBS Tech. News Bull.*, **34**, 137 (October, 1950).

[8] Recording microwave refractometer, *NBS Tech. News Bull.*, **34**, 45 (April, 1950).

humidity standard. In another project, the Office of Basic Instrumentation is studying the possibility of utilizing the hydrogen excitation spectrum for absolute humidity measurements at low temperatures.

Because the neutron has no electric charge, the measurement of neutron energies is a problem quite different from that of electron, proton, or alpha-particle energy measurements. Thus far, methods that have been employed for this purpose have been quite varied in principle. The work on neutron spectrometer evaluation will involve a summary of characteristics of neutron spectrometers now in existence and an evaluation of proposed designs for new types. The project on nucleonic instrumentation will be concerned with the development of fast memory tube-type pulse-height analyzers for nuclear research. It will also attempt to extend the use of memory tubes to other types of nuclear instrumentation. Another project in this field which is now being planned will include the construction and absolute calibration of a standard slow-neutron flux free of gamma rays and the development of instruments and techniques for intercomparison of unknown fluxes with this standard flux.

The projects described above, while not a complete listing, are typical and serve to indicate the scope of the work carried on by the NBS Office of Basic Instrumentation. Continual modification of the program and its objectives may be expected as the science of instrumentation develops and new instruments and measurement techniques become available.

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2. EISENHART, C. *Ibid.*, **110**, 343 (1949).
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4. ———. *Ibid.*, **114**, 3 (1951).
5. THOMAS, F. L. *Monthly Research Rept. Office Naval Research*, January, 1952.

The Basis for a Science of Instrumentology[1]

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CHOICE OF WORDS can sometimes lead to confusion and misunderstanding. Under a title involving the word "instrumentology," I might well be expected not only to discuss instrumentology but even to know what the word means, particularly as contrasted with the more widely used term "instrumentation." Being unable to live up to these expectations, I shall make little use of either word, assuming only that in dealing with instrumentology it is proper to stay close to the concept of quantitative measurement.

We all do things we do not fully understand. Not every housewife who bakes a cake, even a highly successful cake, is well versed in organic chemistry and kinetic theory of gases. Nor do organic chemists themselves always understand *their* concoctions. Man has been measuring and controlling for a long time, and it is no derogatory reflection whatever on the usefulness of this activity to say that we still do not understand it as fully as we wish. Many good men have contributed toward a better general understanding of measurement and control—men such M. F. Behar (*1*), who has been closely identified with the applications, men who combine teaching and engineering, as does C. S. Draper (*2*), and men like the theoretical physicists Leo Szilard (*3*), John von Neumann (*4*), and David Bohm (*5*). In continuing to show today preoccupation with the task of reaching a better grasp of the fundamentals of the field, I wish to make forthright acknowledgment, first to those who by their infinitely varied, down-to-earth practical activities make the field, and make it the fascinating subject for speculation which it is, and second, to those who have contributed to such broader, more theoretical insight as we already have.

Measurement is an activity in which certain devices, instruments, are used. Let us look first at some of the terms reflecting (for example, in the Help Wanted columns) activities more or less closely related to measurement and control. Such activities are displayed in Table 1 in relation to the information concept. For the moment, at least, the words "information" and "thought" are used with the understanding that everybody knows their meanings but nobody can express these meanings in definitions. Since this has always been done with the word "time," we have in a double sense a time-honored precedent.

These activities are carried out both by human beings and by inanimate, or robot, devices. This has been emphasized by putting in the left-hand column terms characteristically applied to robot action and in the right-hand column terms characteristic of the human analogue. This kind of comparison between the human and robot analogues is of definite value in promoting understanding of both.

Now the two words which occur throughout this table are "information" and "thought." The close relation between the two can be illustrated by asking ourselves such a question as this: "Do we generate information when we get a new thought?" The arrangement in the table implies some difference between thought and information, since information is

[1] Presented at Gordon Research Conference, July 27, 1953.

TABLE 1

ACTIVITIES RELATING TO INFORMATION

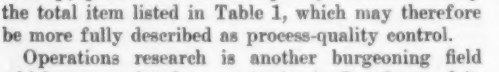
(Robot analogue) Activity	Information	Facility	(Human analogue) Result
Measurement	Generated	Instruments, senses	Thought ingredients
Control	Used	Control effectors, muscles	Deeds (thoughts in action)
Telemetering (communication)	Transmitted	Transmitters and receivers, senses and muscles	Words (thoughts in motion)
Recording	Stored	Memory	Thoughts at rest
Computing	Converted	Brain	Thoughts

shown as being generated in measurement and only "converted" (implying some kind of conservation law) in computing, whereas thoughts are generated in the "thinking process," the human analogue of computing, and the results of sense perception are listed only as "thought-ingredients."

Since the information concept appears throughout Table 1, it seems reasonable to call the field represented by the complete table "information theory." Now we may ask what other similarly broad terms mean in relation to this table. For example, quality control is a rapidly emerging field, already complete with professional society and professional journal. As I see it, quality control is just a special case of control, in which the emphasis is on various features of some product of a process, rather than on a physical variable characteristic of the process itself. Process control is the term usually applied to control of these variables. Together (and indeed with some degree of overlap) process control and quality control make up the total item listed in Table 1, which may therefore be more fully described as process-quality control.

Operations research is another burgeoning field which seems related to our topic. As I understand it, operations research is the effort to apply to various purposeful human activities any relevant scientific knowledge, any useful mathematical techniques (notably, probability theory), and even common sense. So far as I am aware, operations research has as yet no clearly established structure of its own.

To show something of the possible relations between operations research and information theory,



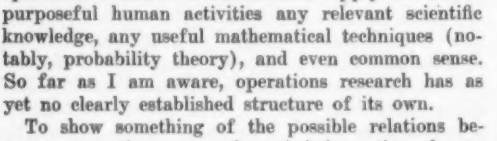


FIG. 1. Comparison of operations research and control.

Fig. 1 compares a general picture of any purposeful activity and a diagram of the more special purposeful activity we call process-quality control. Now if the more general diagram accurately portrays the subject matter of operations research, then control seems to be a subtopic of this discipline. Before accepting this conclusion, however, we should consider the difference between the block diagram of an activity and the block diagram of a system. System implies more or less permanent structure, especially material structure, typified by the aggregates of hardware constituting many physical systems. Activity implies function, interaction of matter and energy, with more emphasis on change and less on static structure. By adopting the viewpoint of the quantum physicist, one can say that system theory eventually dominates. For by sufficiently enlarging the definition of the system (in the limit, if necessary, to include the entire universe), any activity can be described in terms of possible states of the system and transitions between these states.

For those like ourselves who are primarily concerned with aggregates of hardware, the viewpoint of system theory is more immediately useful. But before leaving the subject of operations research, we should notice the important role in it of processes of measurement and observation. The original military work on operations research was based very largely on observations of the actual effectiveness of various military devices. This observation in the field constituted a feedback link very similar to the measuring instruments in our control diagram.

System theory might be called the theory of block diagrams, if we use the blocks primarily to represent more or less permanent physical aggregates, rather than functions or activities. As an example, in the block diagram of control in Fig. 1 each of the three blocks stands for a physically separate or separable aggregate of matter. As regards the general pattern of such diagrams, it is my opinion that the feedback pattern is not in any sense basic to the general theory of block diagrams i.e., to general system theory. The feedback pattern is just one pattern that may show on a block diagram. Its widespread occurrence in biological and physical systems gives it a great practical importance, which should not however be con-

fused with logical importance. (For an opposite opinion, see Ashby [6]). On any block diagram the blocks represent minor systems, the lines represent interaction (flow of matter or energy) between minor systems, and the total pattern of blocks and lines can be regarded as a major system. Information theory is largely the theory of "lines between blocks." Feedback theory becomes one subtopic under "patterns of interaction among systems."

The flow along the lines of a block diagram may represent flow of matter or of energy. The use of a line also to show the input of purpose may perhaps raise some questions. Whether or not "purpose" is a good generic word with which to label such things as set-point input to a controller, I have for the moment simply wished to emphasize what I consider to be the distinctive character of this type of input.

We might try to characterize these flows in terms of three "dimensions" of mass, energy, and information, as suggested by the arrangement shown in Fig. 2. Each of the examples of flow is actually three-

	Matter Flow	Energy Flow	Purpose Flow
Mass	Sand conveyor	Steam pipes	Bullets
Energy	Steam pipes	Electrical power lines	A-bombs
Information	Letter mail	Telephone lines	Propaganda

FIG. 2. Dimensioning of flow lines.

dimensional, since all involve some displacement of mass, of energy, and of information. The vertical position assigned is an indication of the principal dimension of each example.

A further exercise in what may be called dimensioning of flow lines would be to consider four conveyor lines in a plant, one carrying crude, unprocessed ore, another carrying highly purified graphite, a third carrying rough castings of a machine part, and the fourth carrying the same parts precisely finished. Here we have four lines of matter flow which might conceivably be identical in mass flow rate. What is carried by the graphite that is missing in the flow of ore? Chemical thermodynamics can furnish a tolerably complete answer in terms of energy and entropy, and negative entropy may be correlated with information (7). The difference between the finished and unfinished machine parts is more subtle. The problem is one of associating quantity of information with structure—a problem which has not been solved so far as I know, and which is worthy of further attention and effort. It is basic to such types of measurement, for instance, as autoradiography (8).

If we turn now from these broad considerations of the fields of information theory and system theory, we may look for a suitable point on which to concentrate more detailed scrutiny. I think it is the concept of measurement which should get the spotlight, since it is the central concept of instrumentology, and since in it information seems to originate.

The verb "to measure" has two well-established meanings. I shall illustrate them by referring to a grocer waiting on a customer. The customer picks out a watermelon he wishes to buy, and since the grocer sells it by the pound the melon must be weighed. Such a process I shall refer to by the hyphenated term "measure-estimation," since the purpose is to measure (in the sense of estimate) the unknown weight of the melon. Suppose next that the customer asks for five pounds of sugar, which the grocer keeps in bulk in a barrel. To meet this situation the grocer must measure five pounds of sugar, using no doubt the same scales on which he weighed the melon. But this is a fundamentally different process, which I shall call measure-establishment, since this measuring is, in the sense of "measuring out" or "measuring off," the establishment of a known magnitude chosen a priori by the customer.

Measure-estimation is what is now commonly called measurement, and measure-establishment is now commonly called control. The sugar-weighing is the prototype of all our measured, controlled modification of structure, such as precision machine work; of our controlled modification of chemical composition, such as ore processing; of our controlled manipulation of various forms of energy, as in temperature control. Yet in the prototype examples of the grocery store the only significant difference between measure-estimation and measure-establishment seems to be that in one case the customer's initiative was directed to an object (a particular melon) and in the other case to a particular numerical quantity (five pounds).

The results of the two weighings are the same in that in each case a certain magnitude is known, and, assuming the same scales and equally careful manipulation, known to the same accuracy. The a priori situations, however, are different—the melon weight was unknown, the sugar weight was as definite before as

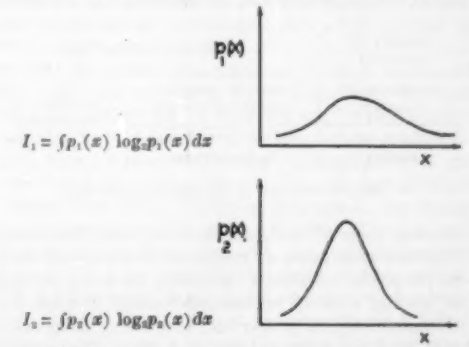


FIG. 3. Information generated in measurement.

after. In the sugar-weighing, something was done; but in the melon-weighing, something was learned. Now comes an essential question: how much was learned? how much information was generated?

Norbert Wiener (*9*) proposes a method for quantitatively specifying the amount of information gained in a measurement. His suggestion may be explained by reference to Fig. 3. Assuming a continuously variable quantity x is being measured, the probability density estimated for x before the measurement is p_1, and after the measurement one has a sharper distribution p_2. Then the information gain is the difference of the two integrals $I_2 - I_1$. There would be a corresponding definition for a discrete variable. Wiener's suggestion seems perfectly workable, provided one can realize the two functions p_1 and p_2. The a posteriori distribution p_2, especially when based on more than one or two observations, can doubtless be taken as a normal distribution with specified mean and specified probable error. But the a priori function p_1 seems difficult to assess, especially when it must be based on only very scanty knowledge. One always has some a priori information, but it is seldom easy to put this estimate in quantitative form.

Let us turn now from the *process* of measurement to the *devices* used—that is, to instruments. We are, of course, studying one problem, whether we phrase it as the study of the device as used in the process or the study of the process as carried out with the help of the device. The choice is one of perspective and emphasis. Looking especially at instruments with a view to classifying (*10*) and specifying them, one is confronted with some questions which are easy and others which are hard to answer. For example, I think it is easy to specify for most instruments the instrument's class, that is, the variable it helps to measure; the instrument's accuracy; its scale range; and its frequency range or its time constants. But there is another important quality of an instrument which in many cases can hardly be given a numerical value.

This is the interaction of the instrument with the system on which it is used. I have designated this quality of an instrument, its efficiency (*11*). Figure 4

measured quantity	efficiency related to:	
property of matter	size of sample change of sample	changes in remainder of universe
form of energy	energy interchange with system	

FIG. 4. Factors in instrument efficiency.

displays some of the factors entering into this concept. The two basic types of measured variables are shown as properties of matter, including chemical composition along with the various mechanical, thermal, electrical, and optical properties; and energy components, such as force, temperature, or voltage. For property measurement an efficient instrument would require only a small sample of matter, and would not change it appreciably (e.g., it would be a "non-destructive" test). For energy component measurement, high instrument efficiency would be reflected primarily in small energy interchange with the system on which the measurement is made—i.e., to which the instrument is coupled. For both types of variables there are other, more peripheral considerations which seem to be related to efficiency. In Fig. 4, these are designated "changes in the remainder of the universe." Thus an instrument which required exorbitant auxiliary power, or one which emitted dense clouds of acrid smoke, or one which weighed several tons, would be in some sense inefficient. It is not clear what role, if any, should be assigned to these peripheral factors in our specification of efficiency.

The most definite central portion of this efficiency concept is the interchanged energy. In this domain it seems reasonable to define efficiency as the ratio of reading to energy exchanged (see Fig. 5). For example, a voltmeter's efficiency would be a ratio of voltage to power. This corresponds to the customary specification of ohms per volt. The corresponding specification for an ammeter would be mhos per ampere. In general, if an instrument measures an energy-component quantity q, efficiency would be the ratio of q to power, or if we define in each case a suitable immittance, of immittance to q. It would doubtless be wise to stick to the convention, observed with voltmeters, of using the full-scale reading as the defining value.

$$\frac{\text{voltage}}{\text{power}} = \frac{\text{voltage}}{\text{current}} \quad \frac{1}{\text{voltage}} = \frac{\text{impedance}}{\text{voltage}} \quad \left(\frac{\text{ohms}}{\text{volt}}\right)$$

$$\frac{\text{current}}{\text{power}} = \frac{\text{current}}{\text{voltage}} \quad \frac{1}{\text{current}} = \frac{\text{admittance}}{\text{current}} \quad \left(\frac{\text{mhos}}{\text{ampere}}\right)$$

$$\frac{q}{\text{power}} = \frac{q}{q^*} \quad \frac{1}{q} = \frac{\text{immittance}}{q}$$

FIG. 5. Efficiency of energy-measuring instruments.

Whatever may be the practical appeal of this usage, it has a fundamental logical importance in denoting the work done *on* the instrument, or the energy input. There is also work done *by* the instrument in making the information known. In many cases this work appears in the rotation of a pointer against a torsional spring. The way in which this "output work," as reflected in sensitivity, may have to be compromised with "input work," as reflected in efficiency, is illustrated in Fig. 6. Here we consider an ammeter of the moving-coil, permanent-magnet type which is carrying a current I sufficient to deflect it through the full-scale angle A. The deflecting torque is the product of this

torque	$SA = BlaI$
efficiency	$e = 1/RI$
for narrow coil	$l \cong cR$
resultant equation	$Ae = \dfrac{Bac}{S}$

FIG. 6. Compromise of sensitivity and efficiency in an electrical meter.

angle with the torsional spring stiffness S. The torque is also given as product of current with magnetic induction B, length of wire l, and radius of coil a. The efficiency e, neglecting reactive impedance, is inversely proportional to coil resistance and to current. For a long narrow coil, the length of wire cutting the magnetic lines is nearly equal to cR, where c is conductivity multiplied by cross-section area of wire in the coil. Combination of these relations shows that full-scale angle and efficiency are inversely proportional to each other. In the proportionality constant, the factor a/S is directly related to the time constant of the movement, and hence to its accuracy in following changes. Thus we have here a simple illustration of the general situation, that accuracy, range, and efficiency are competitive factors of merit which must always be compromised in any given design.

In effecting this compromise in design, it would help to have a more definite picture of the relation of information output, reflected in range and accuracy, to the output work required by various methods of indication. During the past year I have been interested, as part of an ONR-sponsored research (*12*), in comparing the common pointer-scale combination with other indicating means. Though it does not seem possible to summarize quantitatively the many factors, some objective, some subjective, entering into such a comparison, I must say that the pointer-scale method stands the comparison very well.

My general thesis has been that the science of instrumentology must be advanced by clarifying the *activities* and *processes* of measurement and control, both in their essence and in their relation to other activities and processes; and by clarifying and organizing our understanding of the *devices* used in these activities. The specific aspects of these two broad objectives which I have touched upon are, of course, only a few of the many interesting questions calling for solution.

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Into a New Century

THE YEAR 1953 marks the one-hundredth anniversary of the Bausch & Lomb Optical Co. At this milestone the company's pride in its achievements is tempered by the challenge of the future. To that future it dedicates its centennial.

Among those who joined the exodus from Europe in 1849 was John Jacob Bausch, founder of the Bausch & Lomb Optical Co. Arriving in New York, he traveled westward to Buffalo where he worked as a cook's helper and carpenter for several months, then borrowed five dollars, and went to Rochester. There he eventually opened the little optical shop that was destined to become one of the world's leading producers of optical glass, scientific instruments, and ophthalmic products.

If John Jacob Bausch had not lost two fingers in a buzz saw accident in 1852, America might never have been the beneficiary of a company which revolutionized the optical industry and provided some of the critically short materials and instruments necessary to win two world wars. After the accident, Bausch found it necessary to continue part-time work at his trade of woodturning for a year, but the real birth of the world-renowned firm, 100 years ago at Rochester, can be traced to that fateful event. It brought the young German immigrant into contact with a fellow immigrant, Henry Lomb, who had collected twenty-eight dollars for his friend to tide him over his convalescence. When Bausch opened his first optical shop, in 1853, it was with the help of sixty dollars borrowed from this same friend. Bausch demonstrated his sincere appreciation by making Lomb a full partner in the struggling business that same year. In 1868, Lomb entered the Union Army and served as a captain in the 13th regiment, New York Volunteers. He sent home his soldier's pay to keep the small business alive. Neither partner, during their long years of association, found it necessary to have a contract with the other—a notable example of faith and mutual trust.

Like most other beginning enterprises, the young business was beset by many difficulties. The first real promise of success came with the development, by Bausch, of a spectacle frame made of hard rubber. The kitchen range in his home served as shop laboratory for this first "plastic" eyewear. From this, the little shop became a successful manufacturing enterprise. Previous to this development, the only plastic

frames available were constructed from horn, a material which was difficult to shape and which demonstrated a tendency to split. Experiments proved the hard rubber to be superior in many respects to the horn, but, more important, it readily lent itself to mass production. Spectacles could now be made in quantity and at a reduced cost.

For sixty-nine years, Edward and William, the two sons of J. J. Bausch worked together in the company until their deaths in 1944. Edward Bausch, trained at Cornell University, foresaw the need of science for more microscopes. In 1874, when only fifty such instruments existed in the United States, he set about to develop mass-production machine methods for their manufacture. Such methods, in his lifetime, made microscopes available at moderate cost to laboratories and schools throughout the world—a contribution of untold value to scientific and technological progress. William Bausch was a pioneer in the production of optical glass in America. His earlier successful experiments became of prime importance at the outbreak of World War I, when with the help of the Geophysical Laboratories of the Carnegie Institution, Bausch & Lomb served as the principal source for optical glass, freeing America from dependence on foreign sources for this critical material.

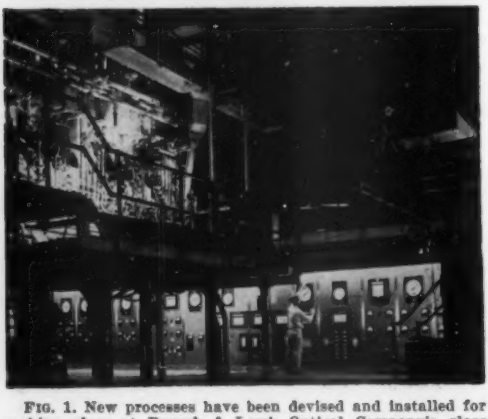

FIG. 1. New processes have been devised and installed for making glass at Bausch & Lomb Optical Company's glass plant which was started in 1913 and was the principal source of supply for the United States during World Wars I and II. Here a glass technician takes a temperature reading of molten, white-hot glass in one section of the huge plant located along the Genesee River bank.

In 1861, Bausch & Lomb further advanced the possibility of better vision by introducing power lens-grinding machinery into the United States. The former laborious manual operation was thus eliminated, and the cost of spectacles was reduced to an even greater extent than it had been by the advent of hard rubber frames.

It is a far cry from J. J. Bausch's first little shop in the Reynolds Arcade to the modern organization and its global affiliation. Besides the main plant in Rochester, totaling 1,500,000 square feet of floor space, there

FIG. 2. Approximately 22 hours are needed to complete the melt under accurate control of all furnace conditions. This includes 7–8 hours for the melting process, 7–8 hours for the fining process whereby bubbles are removed and the liquid stirred, and 6–7 hours to cool the molten glass slowly to a temperature suitable for rolling. Here the molten glass, like a giant pot of taffy, is to be poured on a cast-iron table for rolling into a sheet.

are four other factories in the United States, Canada, and Brazil. Sales outlets include more than 170 branch offices in this country and abroad, and personnel now number over 8000.

Another kind of growth, however, is in the company's concepts of its primary purpose. Simply stated, that purpose today is to make all products that best serve the optical and visual needs of mankind. This calls for an enlarged engineering staff for research and product design, modern manufacturing facilities for efficient quality production, and progressive practices in all other phases of modern management.

Nothing is more important to the manufacturer of optical instruments and ophthalmic products than optical glass, for the performance of any optical part depends on the properties and qualities of the glass from which it is made. Optical glass is as different from ordinary glass as the steel in a fine watch spring differs from that in a tenpenny nail. A fundamental requirement of optical glass is homogeneity. Even a slight departure from a high degree of uniformity in composition is intolerable because of the effect on the performance of the finished instrument. It must have definite refractive indices for different wavelengths and accurate dispersion ratios. It must be free from color, striae, bubbles, inclusions, and cloudiness.

For decades, the Bausch & Lomb Glass Plant has been devoted exclusively to the production of optical glass, a manufacturing operation of considerable proportion. Here, in the year just passed, 2,500,000 pounds of sand, along with sixty other ingredients, went into the manufacture of 3,500,000 pounds of glass, of 120 distinct types. This glass produced 22,500,000 pressings and required 468,000,000 cubic feet of gas.

Foreign labor rates still make it possible to purchase optical glass abroad more cheaply than it can be made

here, but the Bausch & Lomb Glass Plant has been continuously maintained since World War I because of the technological advantages which its existence affords the United States. Continuous quality control, from sand to finished product, is an asset of inestimable value.

FIG. 3. Before reaching the finished state, a lens must undergo many hours of grinding and polishing.

Approximately 120 different types of optical and ophthalmic glass are manufactured. Among these are many types pioneered by the company to keep pace with, and in several cases to anticipate, the new scientific developments in many different fields. As the demand for larger lenses in certain applications developed, revolutionary new methods were formulated for making a glass of the particularly high quality necessary in the manufacture of such lenses. The company's chemists assisted U.S. Navy scientists in developing a supersensitive type of glass that can detect the presence of atomic energy. After exposure to high-energy radiation, this dosimeter glass remains unchanged in appearance under ordinary light, but reveals the extent of exposure by the amount of orange fluorescence it emits under ultraviolet rays.

Design of product is a responsibility of the Research and Engineering Division. On its staff of 300 are many scientists and technicians engaged in original research —optical, electronic, chemical. Their specialized knowledge embraces all scientific fields served by the company.

New colors for use in Ray Ban sun glasses and filters have been developed. Revolutionary new types of glass for safety eyewear have been produced. From

FIG. 4. Over 400 operations are needed in the manufacture of frames and mountings. Shown here are a few steps in the manufacture of gold-filled wire. Sheets of 12-carat gold are blanked into disks, drawn into cups, then into cylinders. Cores of base metal, wrapped with thin sheets of solder, are inserted in cylinders and bonded under high temperature. Cylinders are reduced in diameter by being drawn to desired size. Wire is then ready for use in manufacturing.

the very outset, Bausch & Lomb has been particularly concerned with the manufacture and constant improvement of ophthalmic eyewear. Early in the twentieth century, members of the firm suggested to Dr. Moritz von Rohr, of Jena, the development of a scientifically correct series of such eyewear. Von Rohr set himself the task of developing a series that would embody the advantages of all existing types and that would remove their limitations. He followed the work of Wollastow and Ostwalt, making no claim to the invention of astigmatically corrected lenses in the spherical powers, but devoting his investigations to compound lenses that employed toric surfaces. He made thousands of computations of spherocylindrical combinations over the entire range of powers to determine the exact formulas for compound lenses that would give the required powers in the two meridians, and at the same time give equally distinct vision from center to margin. He announced his results in 1911, and in 1914 Bausch & Lomb introduced Punktals to the American market. Thus it continued von Rohr's work by adding eighth and quarter diopter intervals wherever necessary, by recomputing the lenses with reduced center thickness, and by later making Punktal Kryptoks and Punktal Ultex. The attributes of the Punktal received even wider recognition with the introduction of the Bausch & Lomb Orthogon series, which employs group curves, each lens within a group being made with the same base curve and the entire series employing as many base or group curves as the requirements of marginal correction demand.

For years scientists sought some way of removing the visible dividing line in cemented bifocals. The introduction of fused bifocals remedied this defect; but objectionable color fringes, due to the nature of the glass in the segment, still marred their perfection. Intensive experiments in the glass plant of Bausch &

Lomb finally produced a new type of dense barium crown glass having the high refractive index of flint glass and the low color dispersion of ophthalmic crown glass. At the same time, its coefficients of expansion and contraction, its melting point, and its other physical properties were suitable for perfect fusing. The result was the famous Nokrome lens, a bifocal without noticeable color or dividing line. In the fall of 1930 the successful development of the Hammon patent was achieved. This was the ingenious and justly celebrated Panoptik. It was the first fused bifocal in which a reading segment, with or without prism, of any desired shape or size could be incorporated.

In the design and construction of ophthalmic instruments, Bausch & Lomb has been identified with the foremost authorities of Europe and America since 1890. In this country, the company proposed the new system of lens measuring known as vertex refraction and supplied the vertex dioptrometer for this purpose. In order to insure correct focus, the vertex refraction system of numbering lenses was introduced, so that any two lenses of the same vertex refraction would give precisely the same correcting effect, regardless of their shape.

The blind spot of the eye has been studied for years, since its discovery by Mariotte in 1668. Much more recently, in this country, Dr. Ralph I. Lloyd had given it considerable attention, using hand stereoscopes. Not satisfied with his own progress in this direction, he appealed to Dr. Max Poser of Bausch & Lomb for a stereoscope which would give a field ten degrees above, below, and internally, twenty-five degrees externally, and free from color faults. The instrument must give this field without increasing the lens or prism strength. Lloyd gave this report on the result: "He [Poser] supplied an instrument with a field far surpassing our hopes. It covered the usual field internally, 30° above and below, and 40° externally." This instrument, known as the Lloyd's Stereo Campimeter, combined the advantages of binocular fixation and the tangent screen.

The early success of Bausch & Lomb with the binocular corneal microscope was due to a broad understanding of microscope optics and the application of this science to the study of the eye. Previously, it had been difficult, with monocular vision, to locate slight defects or injuries to the cornea. This deficiency was corrected with binocular vision in which the largest possible field was obtained with a marked stereoscopic effect.

The company also had the privilege of working with Professor Allvar Gullstraud of Upsala, Sweden, on the ophthalmoscope, and later of perfecting an instrument in which the macular area and the optic disk appear in the same field at the same time. The field of view is approximately four times that of the hand ophthalmoscope. In the objective measurement of corneal curvatures, the Keratometer offers the easiest and most accurate method known. Its coincidence system of focusing, a Bausch & Lomb feature, speeds prompt and accurate location of the axis.

Always alert to the requirements of the optical profession, authorities in the ophthalmic field have been encouraged in their search for new or improved instruments. From this collaboration have come such instruments as the perimeter and projector devised by Doctors Ferree and Rand of the Wilmer Institute, the Clason visual acuity meter, Green's refractor, and the Universal and Poser slit lamps.

Probably no single instrument has contributed as much to scientific progress as the microscope. In 1876 there were less than 100 microscopes in the United States. Largely through an improvement in production methods microscopes were made available at modest cost to universities and laboratories. Since that time Bausch & Lomb scientists and technicians have pioneered in the development of more efficient microscopes of all types. The ball-bearing microscope, the variable-focus condenser, the prefocusing gage, and many other new developments, have been introduced.

In our present-day world, spectrography is widely used for the rapid identification and quantitative measurement of substances, both known and unknown. Spectrographic analysis has become indispensable to science and industry. Bausch & Lomb can take particular pride in the role it has played in bringing to the attention of scientists all over the world the advantages offered by the spectrographic method.

In 1953 the company demonstrated, for the first time, a spectrograph that is the culmination of its efforts to date to provide the best tools in the spectrographic field, the Littrow-echelle spectrograph. The new concept employed in this instrument deals with the properties of a new optical element known as an echelle, first conceived by Dr. George R. Harrison, Dean of Science at the Massachusetts Institute of Technology and special consultant to Bausch & Lomb. As used in the new instrument, an echelle is an inch-thick, optically flat glass plate three by five inches, in which grooves have been precisely ground, 200 to the inch. The first and only echelles ever made have been produced since 1949 by Bausch & Lomb. Like the diffraction grating, the echelle disperses light into a spectrum; but its dispersion is considerably greater, thus permitting the distinguishing of spectral lines as separate even when they are only a fraction of an angstrom apart. It makes possible the design of high dispersion spectrographs with focal lengths only one-ninth (or less) of those previously possible with grating spectrographs. Assuming a 200-groove-per-inch echelle and a 15,000 groove-per-inch grating (in the second order), the theoretical resolving power at 5000 A for six inches of ruled width would be 180,000 for the grating and 537,000 for the echelle. In addition, the echelle, in combination with a prism or grating, produces a two-dimensional spectrum, as contrasted to the one-dimensional spectrum produced by the grating or prism alone. Thus, research scientists are able to gain more quickly far more complete information about the substance being studied, and to gain it from a fewer number of photographic plates.

Most people who have some lay knowledge of

gratings are impressed by the number of parallel lines cut into the aluminum film with which gratings are coated. A grating recently produced in the Bausch & Lomb Grating Laboratory for the University of California's Los Alamos atomic laboratory was ruled 30,800 grooves to the inch—an impressive number, statistically, but it tells only part of the story. Of equal importance is the manufacturer's ability to shape the grooves so that they are always parallel and reflect light in a specified direction. This is called blazing. Its accuracy depends on the precision of the grating engine, the patience and care shown by the operator in adjusting the ruling diamond, complete freedom from vibration and from temperature and humidity changes during manufacturing, and a storehouse of technical information and know-how. The success of a grating depends then, not only upon the number of grooves but also upon the nature of the grooves. The manufacturing process used in the making of gratings has been brought to a level of precision and accuracy that makes them among the world's finest.

In 1935 Bausch & Lomb entered the photogrammetric field by developing a line of photographic instruments for military engineers. These first instruments were designed around a narrow angle lens (67°), but within a short time the Metrogon lens was developed with an angle of 93°. Soon there was a demand to design multiplex equipment for this lens. Today it is still regarded as one of the finest lenses for this purpose in the world and is used universally.

Not satisfied, the company has recently developed the Cartogon lens, which will reduce distortion by as much as 10 per cent over that of the Metrogon lens. It has also developed the auto focus rectifier to meet the high volume needs of the government services and commercial concerns in the rectification of tilted aerial photographs. This instrument embodies a mechanism that allows a layman with little training to rectify photographs quickly, without the need for complicated computations. It is the only instrument of its type produced in the United States.

At present, Bausch & Lomb is building Twinplex Plotters for the U.S. Geological Survey Service. The development of this instrument will make possible the use of convergent photography and thus considerably reduce the time necessary to complete the task, now in progress, of mapping the United States.

More of the world is being mapped with the use of this company's photogrammetric equipment than with any other. As one of the pioneers in this field its research laboratories are constantly seeking to develop new equipment that will make the task of mapping increasingly simple and more accurate.

Far from being a recent development, the principle of evaporating thin metal films on glass surfaces dates back to the close of the nineteenth century when Thomas A. Edison took out a patent on the process. In 1892, H. Dennis Taylor, a celebrated lens designer, found that certain types of photographic lenses were faster after their surfaces had been tarnished by age, a fact which suggested to him that it might be possible to devise a process by which the same effect could be produced artificially. From these beginnings, thin film technology has matured to a position of scientific importance. Today's thin films are possible only because of the improvements made in techniques and apparatus during the last twelve or thirteen years.

In 1940, when the new Technicolor movie *Gone With the Wind* was first shown, the prints were found to be too dark. Some means had to be provided for throwing additional light on the screen. The solution was reached with Balcoted Bausch & Lomb Super-Cinephor projection lenses. From this point on, Bausch & Lomb assumed a leading position in the field of lens coatings. A few of the major developments since 1940 have been the anti-vignetting filter for wide-angle lenses, the introduction of Ray-Ban gradient density sun glasses, the interference and interference wedge filters, heat-reflecting filters, and a long list of many others. Research in this direction continues at a rapid pace under the direction of Dr. A. F. Turner, a world-wide authority on lens coatings.

The success of the newest cinematographic process, known as Cinemascope, depends in the main on the anamorphic lenses, first invented by Dr. Henri Chrétien of Paris, and improved by Bausch & Lomb, the sole manufacturer of such lenses in this country.

Cinematography, television, astronomy, photography, illustrated magazines, and newspapers require the use of optical systems or processes. The school teacher with a microprojector, the food processor with the refractometer, the forest ranger with a binocular, the master machinist with the contour-measuring projector, the sportsman with a telescopic hunting sight, each reflects one small facet of optical science at work in our modern society. With its tradition of integrity, resoursefulness, and perseverance, Bausch & Lomb, can justifiably be proud of the part it has played in supplying them with the finest of optical tools.

These are but a few of the accomplishments of the past century. More will come as the shaping of new scientific projects is translated into optical needs. New and better manufacturing methods are in the course of development. The past is an inspiration for the future, a future that is viewed with hope and confidence.

Electron Interferometry

L. Marton

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THE UNWARY READER, seeing the combination of the words "interferometry" and "electron," may wonder about its significance. It is used here in the same way as in "electron optics" and its various branches such as electron microscopy. Thus electron interferometry means the use of electrons in place of light in interferometric systems.

For the past twenty-five years, many efforts have been made to build up a new discipline called electron optics, starting with the establishment of analogies between this and the geometrical optics of light. Many of the old and well-known effects have been catalogued and their places among the newer ones established. With the building up of this truly impressive edifice came increased insight into the operation of some older devices and at the same time the design of new and unexpected instruments.[1]

It is somewhat surprising that, although the geometrical analogue was emphasized, little effort was made to build up the physical optics of the electron. Some signs pointed in that direction. After all, even the resolving power of the electron microscope cannot be adequately explained without considerations of the wave nature of the electron. Also, the time came when it was necessary to work out the wave theory of aberrations in close analogy to light optics. However, the efforts were restricted to the wave-mechanical approach to geometrical optics and any efforts to build up the systematics of physical electron optics were still lacking.

I believe that the time has come when a systematic approach to physical electron optics is a necessity. Physical optics can be defined, in close analogy to light optics, as that branch of optics where the wave concept is essential and where the ray approximation becomes insufficient. In that sense physical electron optics encompasses phenomena of electron diffraction, electron interferences, electron scattering, and electron polarization. There may be other phenomena belonging in this category, but these four important subgroups constitute the bulk of what may properly be defined as physical electron optics. Electron optics as defined above is the physics of beams of free electrons; it is analogous to light optics, the physics of beams of photons.

The different branches of physical electron optics enumerated above have received varying degrees of attention in past years. The first to be known and studied was electron scattering, although at the beginning the study was entirely phenomenological. Since the advent of quantum mechanics, electron scattering has emerged from that primitive stage and today quite an amount of knowledge, both experimental and theoretical, has been accumulated on that subject.

Next was the discovery of electron diffraction, which for all practical purposes was contemporary with the advent of wave mechanics. This has since become a powerful tool for the exploration and determination of the structure of solids.

Electron polarization is rather little known. There have been definite attempts undertaken to observe polarized electron beams, but efforts have been rather fragmentary.

I have left the discussion of electron interferences to the last because their study is just beginning. This does not mean that electron interferences have not been observed in the past; ever since electron diffraction has been observed, we have seen electron interference phenomena. It may be said that we cannot have electron diffraction without electron interferences, but for all practical purposes we can have electron interferences without electron diffraction. The same is true for light, of course, where observation of diffraction is almost invariably accompanied by interference phenomena. Thus, electron interferences, while historically far from new, did not play a serious role in the physics of the free electron until quite recently.

A little over two years ago, Uyeda and collaborators (*1*) described a new type of effect which was observed in certain electron micrographs of graphite flakes. This consisted of equidistant dark bands running across the electron microscope image, which have been interpreted as interference fringes produced by the wedge-shaped flaking off of the lamellar crystals. In a recent paper, Rang (*2*) describes a different type of electron-interference phenomenon. It is seen when blisters produced in a thin layer of lead iodide are observed with an electron microscope. Because the front and back walls of the blister act as interferometer plates, interference fringes are observed across the image. To use a somewhat crude analogy, we may compare the observation of these two kinds of phenomenon to two distinct steps in the light-optical observation of interferences. The first observation of light interference phenomena was probably on oil slicks or other thin layers accidentally produced by nature. The next step was man-made surfaces put together to imitate some of these colorful phenomena, and thus were Newton's rings born. I should like to compare Uyeda's beautiful observation to the colored fringes found on oil slicks; and since Rang's experi-

[1] Good reading material on the subject of geometrical electron optics is contained in the books of W. Glaser, *Elektronenoptik*, Springer, Vienna, 1952; O. Klemperer, *Electron Optics*, Cambridge University Press, 1953; V. E. Cosslett, *Electron Optics*, Oxford Unviersity Press, 1950.

ment presents a more purposeful production of interferences, it may be compared to Newton's rings.

The decisive step in light optics was made by Young who finally established the wave theory of light, originally formulated by Huygens in 1678. Young created, about 1800, a system in which interferences can be produced at will and manipulated for measuring purposes, and from his experiments were derived all the modern light interferometers. The development of electron optics was not nearly as drawn-out as that of light optics. The conception of a workable electron interferometer (*3*) predates the publication of Uyeda's paper and the first definite results by means of such an instrument (*4*) were published almost simultaneously with Rang's paper.[2]

In the preceding considerations, I have freely used the analogy of light optics, not only because our concepts were based on such analogies, but also because their use conjures up images that make the understanding of the steps and of the phenomena much easier. This applies even more when we come to a discussion of the possibilities of electron interferometry and the means of realizing them. As in light optics, there exist essentially two distinct methods for the production of an interferometric measuring system. One is derived directly from Young's experiment. If a double slit is illuminated by coherent light issuing from a small source and if means for reuniting the two "rays," say in the shape of a lens, are provided, interference fringes can be observed in the image plane by such a lens. Many variants of this principle have been worked out and, in particular, the Rayleigh interference refractometer was derived from this principle. Its essential feature is that a spherical or cylindrical wave front, issuing from the point-like or line-shaped source, is split by means of a double slit into two separate narrow beams. The limitations of this kind of system are best indicated by the common name of the instrument, narrow-beam interferometer.

More commonly used are instruments known as wide-beam interferometers, the best known example of which is Michelson's interferometer. In this device an essentially parallel beam of light is split in two equal parts by means of a semitransparent mirror, and other mirrors (both semitransparent and fully reflecting) are used for bringing the two halves of the beam together again. The really distinctive feature of this kind of instrument is that the amplitude of the wave is split instead of the wave front. The advantages are well known. It is an instrument with a wide field of view and an enormously enhanced intensity, as compared with the narrow-beam instrument where many of the dimensions are very critical.

In attempting to build an electron interferometer, we first discarded any idea of using amplitude splitting—electron optics does not possess any true-reflecting and much less any semireflecting mirrors. In the absence of any such optical elements, our thinking gravitated toward an imitation of Young's experiment, or perhaps of Rayleigh's instrument. Unfortunately, conditions for such an experiment are extremely unfavorable.

Without saying at this point whether a scaling down of the light-optical consideration is justified, let us assume that we could calculate all the dimensions of such an experiment from a light optical model, substituting the short wavelength of the electron. The result of such calculation, or estimate of dimensions, is simply horrifying. For an electron wavelength of let us say 0.05 angstrom unit (which is a reasonable value for electron optical experiments) the slit dimensions would be somewhere between 10 and 100 angstrom units. The separation of the two slits would be about 10 times the slit width itself. To illuminate that double-slit system, we should need an electron source of about the same dimensions as the slit width. Under the assumed conditions, the experiment would yield fringes with a spacing of roughly 100 angstrom units.

Even assuming that we could create slits of this minute width and spacing, we still should not have solved the problem of the slit illumination. It has been demonstrated, however, by Gabor (*5*) that the reduced image of an electron source of reasonable physical dimensions could be used for illuminating such a system; and we may therefore assume that we could illuminate the slits by using an inverted electron microscope and operating our interferometer system by using a virtual instead of a real source. The next problem would be the viewing of fringes with 100-angstrom spacing. Obviously, we should have to use another electron microscope to make them visible. Therefore, an experiment such as this would consist of an instrument comprising two electron microscopes arranged head-on and a slit system between them that we do not yet know how to make. To my knowledge no one has yet had the courage to attempt this complicated instrumentation.

Having ascertained that the wave-front splitting system appeared to be impractical, we had to look for an amplitude-splitting system as the real solution. The mental block to the building of such a system is created by the high efficiency of the light-optical beam splitters. We had thought only of looking for something as efficient as a semisilvered mirror and neglected to look for less efficient systems. By abandoning the limitation of equal intensities of the two beams issuing from the beam splitter, we were able to look around for other beam splitters. The following description of a practical electron interferometer uses such a beam splitter; it is not very efficient in terms of a semitransparent mirror but is highly useful for electrons. I refer to the application of diffraction as a beam-splitting mechanism and its consistent use in an interferometrical system.

To describe an electron interferometer, let us look first at its light-optical counterpart. When a beam of light is sent through a transparent diffraction grating, part of the beam is transmitted and part of it is dif-

[2] Work on the electron interferometer at the National Bureau of Standards is part of a cooperative program of basic instrumentation research and development sponsored by the Office of Naval Research, the Air Research and Development Command, and the Atomic Energy Commission.

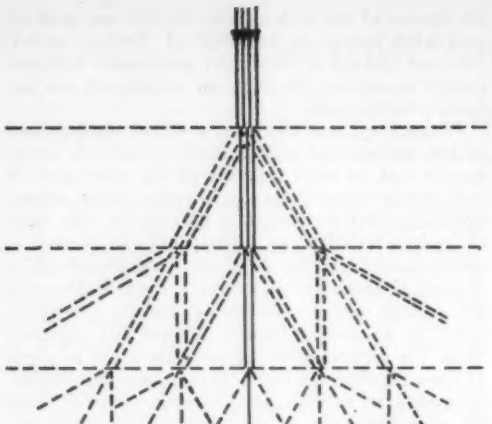

FIG. 1. Schematic representation of rays passing through three gratings (or crystals). Courtesy of *The Physical Review.*

fracted. Figure 1 shows only the first order diffraction and neglects any higher orders. By placing a second transparent diffraction grating at a certain distance parallel to the first one, it can be seen that the transmitted beam is again broken up into transmitted and diffracted components. The same applies to the beam diffracted by the first grating; this will be diffracted again on the second grating. At a distance from the second grating that is equal to the distance of the second from the first grating, a twice-diffracted beam meets up with a once-diffracted one. In placing at that point a third grating parallel to the first and second ones, and by placing convenient apertures, we can bring together, as shown in Fig. 2, two beams that have been diffracted twice.

Translating such a system into the language of electron optics is relatively simple, in principle. All we have to do is use electron beams instead of light beams and thin lamellar crystals instead of diffraction gratings.

The idea of using diffraction as a beam-splitting element is less revolutionary than it seems at first. When originally thinking of that system, I could not find anyone who knew of its light-optical counterpart. It is rather amusing, however, to report that this principle has been used more than 40 years ago in light optics by Carl Barus (*6*), who reported on it in several volumes published by the Carnegie Institution of Washington. For reasons that are not quite clear, none of the optical textbooks and treatises refer to the work of Barus, and I should like to use this opportunity to pay him belated homage.

In addition to the one described above, many other arrangements can be made to satisfy the conditions of interferometry. These include arrangements of crystals plus other electron optical elements or other electron optical elements alone. Some of these arrangements are more critical in that they require greater accuracy in the making or aligning of the optical element. It would take up too much space to discuss here the advantages and disadvantages of several interferometric combinations. The arrangement illustrated in Figs. 1 and 2 is the one proved most advantageous for the first experiment carried out at the National Bureau of Standards; a few more words about the details should be included here.[3]

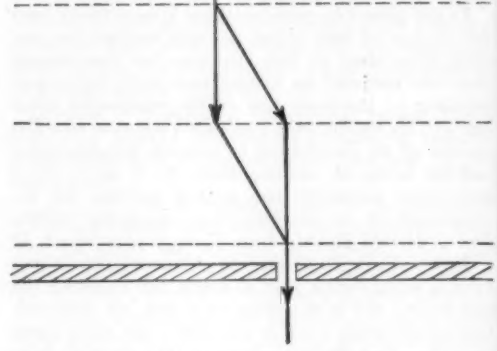

FIG. 2. Rays as limited by apertures. Courtesy of *The Physical Review.*

The thin crystals used for carrying out the experiment are metallic foils of about 100 angstrom units thickness, which have been grown on the cleavage face of a rock-salt crystal. If a thin layer of metal is deposited on such a rock-salt surface, which is heated to a selected temperature, complete alignment of the atoms within the metal layer, forming a single crystal, can be observed. For details of this process, known as epitaxy, reference is made to the literature (*7*). Good

[3] Let us investigate briefly the implications of this experiment from the point of view of the feasibility of an x-ray interferometer. It appears that such an instrument could be built, although the experiment may be a rather difficult one to carry out. Beam splitting, using diffraction or other optical phenomena, seems to be just as easy to achieve as for electrons. The difficulty will arise in aligning the optical elements and in observing the fringes. Present x-ray optics, using curved surfaces at grazing incidence (P. Kirkpatrick, *Nature*, **166**, 251 [1950]), can resolve distances of the order of 10^{-4} cm. A rather good alignment is needed to produce fringes of that spacing. This is where the greater resolving power of electron optics has proved of great value; we did not need the perfect alignment to observe fringes.

The various difficulties mentioned here should not discourage would-be investigators. There are at least two good reasons for undertaking this experiment. One is to check the absolute values of x-ray wavelengths. The other is to measure the length of the wavepacket for x-rays. On this last subject there exist some theoretical predictions which, to my knowledge, have never been submitted to experimental verification. (See, for instance, W. Kossel's paper in: C. Ramsauer, *Das freie Elektron in Physik und Technik*, p. 130, Berlin: Springer, 1940.) Such an experiment thus could contribute considerably to our knowledge of radiations.

single crystals of different metals, such as gold, silver, copper, nickel, and others, can be produced in this manner and are useful beam splitters for the electron interferometer.

For the practical achievement of the electron interferometry experiment, a modified electron microscope can be used. The electron microscope comprises optical elements that are needed for any successful interferometry work, that is, it has a beam-generating system, a beam-collimating system, and an electron optical system for the purpose of viewing the fringes. The experiment is thus carried out by replacing the object chamber of the conventional electron microscope with an interferometer chamber.

The first experiments, which confirmed the feasibility of the interferometer, had to be carried out entirely by means of photographic observation because the total available beam intensity was too low for visual alignment of the instrument by means of a fluorescent screen. This was, to put it mildly, tedious work; but, finally, proof is on hand that interference fringes that can be manipulated at will by changing the instrument parameters can be produced by means of electrons.

An interesting property of this interferometer is that it is achromatic. This means that its light-optical analogue produces fringes in white light and no monochromatic light source is required for its operation. This is because diffraction deflects the different wavelengths by different amounts and thus the instrument, so to say, has its own built-in monochromator. To be quite frank, this property was not recognized at the time the instrument was conceived. Later on, however, it proved quite advantageous during the experiments to find that the requirements on wavelength constancy (i.e., stability of the high-voltage power supply) were very much relaxed. This was one good reason for pushing the experiments with the three crystal arrangements (shown in Figs. 1 and 2) and putting in the background the search for other nonachromatic instruments.

The question invariably arises, what is this experiment good for?

There are a certain number of applications of the instrument in close analogy to the light interferometer. For instance, it could be used in extending the range of the light instrument in measuring shorter distances than were previously feasible. It should be well understood that this does not mean that it may supplant the light interferometer, for the upper limit of its operating range will be lower than that of its predecessor. It is a situation somewhat similar to that of the light microscope and the electron microscope. The two are complementary and not competitive. There exist other applications, such as the measurement of very weak field gradients, determination of Planck's constant, and interference spectroscopy, but the application that I want to discuss a little more in detail here is the improvement of our fundamental knowledge of the electron itself.

In all the description up to now I have avoided reference to the electron as a particle. Now, in order to state in what manner the interferometer can contribute to a better knowledge of the nature of the electron, I can no longer avoid referring to the old particle-wave concept. Let us start out by stating again that the building up of the electron interferometer was based entirely on a light-optical analogy. That means that all the design parameters were calculated by scaling down from a light-optical model by substituting the shorter wavelength of the electron for the light wavelength, the lattice constant of the crystals for the grating constant, and the electron diffraction angle for the light diffraction angle. The properties of the instrument including such features as the fringe spacing and the variation of that spacing with mechanical changes could then be calculated. The final observations showed surprisingly good agreement with this rather simple-minded model. In other words, not only does the electron behave like a wave, but in some respects this wave-like behavior exceeds our expectations.

To explain this last sentence I have to add that, although in principle the interference phenomena described here could be calculated on a straight quantum mechanical basis, to my knowledge no attempts have been made up to now in that direction. The difficulties of such a calculation are considerable, one of the complications being due to the dispersive nature of the medium in which the electrons propagate. Here again I need an added explanation: by dispersive it is meant that different wavelengths travel with different velocities. If we compare this behavior of electrons with that of light there is a marked difference. In the case of light, all wavelengths travel in vacuum with the same velocity. This is not true for material media, but gases, for instance, are so little dispersive that in calculating normal light optical instruments the contribution of air within the system can usually be neglected. No such simplification can be afforded for electron optical systems because even vacuum in absence of any fields is a dispersive medium for electrons. This means that the quantum mechanical calculation of intensity distribution in the interference pattern is complicated by the dispersive property of the medium of propagation, and this may be a partial explanation for the missing attempts in that direction. Several physicists, however, have made predictions on the outcome of the interferometer experiment based on "intuitive extrapolation." Although these predictions were rather unfavorable, the results of the experiments exceed these expectations in that the limit of experimental accuracy is much more favorable than was foreseen. Besides this disagreement with the extrapolation (which could be disregarded as based on insufficient experimental evidence), the interferometer experiment extended our knowledge of the electron in the following way: Within the limits of the present experiment, the exceedingly complex quantum mechanical calculations can be advantageously replaced by the much simpler scaled-down light-optical picture.

For those who are interested in specific details of interferometry: on one interferogram, 154 interference

fringes were counted with an average spacing of 1650 angstrom units. The optical path difference, which was not measured directly but calculated from fringe spacing, was 276 angstrom units, or roughly corresponding to 5800 electron wavelengths.

The results of the experiment have shown that (*a*) a wave analogy can be successfully applied in describing the outcome of the experiment, and (*b*) the lower limit of the length of the "wavepacket" is at least 30 times greater than previous experimental evidence indicated. The length of the wavepacket denotes the length of that "coherent" wavetrain within the boundaries of which interference is possible (and thus by inference the phase relationship is not disturbed). The previous experimental evidence was based on observations of resolution in diffraction diagrams, which showed that the wavepacket had to be at least 200 wavelengths long to explain the observed data. Both the older estimates and our new results are considerably below the theoretically possible length of the wavepacket.

The numerical values for comparison can be presented in different ways. One rather striking representation consists of translating the length of the wavetrain into the time required for the "particle" to travel a distance equal to the path difference. According to the present measurement this time (the "coherence time" of the electron) is at least 2×10^{-16} sec,[4] whereas the older lower limit was 7×10^{-18} sec. The theoretical estimate involves a knowledge of the indeterminacy of energy of the electron; for electrons issuing from hot tungsten filaments it could be as high as 10^{-13} sec.

An experiment of this kind strengthens considerably the concept of the wave nature of the electron, and the question may arise whether any more strengthening of this concept is necessary. Another question can be asked: How does such an experiment affect our views of the "true" nature of the electron? Is the electron less of a particle than it used to be because of any such experiments? The answer to such questions may seem trivial, but several recent publications by outstanding theoretical physicists show that it is far from being trivial to the general scientific public (*8–10*). For this reason, I would like to add a brief summary of our present picture as it appears to an experimental physicist.

[4] This time is equal to the path difference of 276A (or 2.76×10^{-6} cm) divided by an electron velocity of about 1.4×10^{10} cm/sec.

There seems to be no reason for further discussion as to whether the electron is a particle or a wave, or as Eddington put it a "wavicle." The electron is none of them. With due apologies to the late Gertrude Stein, the electron is an electron. Old and conventional language cannot be used to describe the properties of something of which we had not the slightest inkling fifty years ago. If we say "particle," the word has certain connotations even in the most abstract mind. We conjure up the image of something solid like a ball or a bullet and try to adapt the properties of the so-called particle to the image in our minds. This kind of operation is feasible as long as there is a common understanding of how the image or model is to be used. For instance, if I call an object a stone by training or by habit or by both, I shall describe certain properties such as shape, color, mass, rigidity, and hardness. I will know that I have an object on hand which, if of proper size and structure, can be cut and used as a constructive element in building houses. The word electron has to convey to our senses a physical entity, which has charge and mass, can interact with fields of forces (both microscopic and macroscopic), can acquire and transfer momentum, and can show diffraction and interference phenomena. All such and other properties are contained in the word "electron." If I want to employ images or models, I can say that under specific conditions of the experiment we can describe the behavior of the electron as particle-like or wave-like, but let us remain conscious that when doing so we are trespassing the limitations of our language. It is about time to repeat and emphasize the warning quoted in Margenau's book: "Thou Shalt Not Make Unto Thee Any Graven Image."

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Processing of Two-Dimensional Patterns by Scanning Techniques

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IN THE STUDY of visual perception and of the processes involved in the recognition and recollections of patterns, it is desirable to have mechanisms available to manipulate two-dimensional patterns. Although such operations might be accomplished, to some extent, by manual means or by special techniques using photographic processes, it appeared that there would be considerable advantages in the great rapidity of action and flexibility that may be obtained by the use of electro-optical scanning techniques.

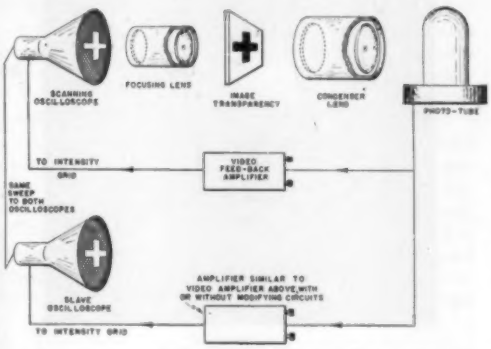

FIG. 1. Image feedback system. Block diagram of apparatus. The scanning spot is focused on the transparency. The transmitted light is converted to electrical signal by the phototube and fed back to the intensity grid of the scanner, thus producing a negative picture on the face of the scanner. The same video signal is modified and displayed on a second slave oscilloscope.

Those considerations led the senior author to suggest that manipulations of a pattern could very conveniently be studied by the system described herein. As a result of this suggestion the equipment described below has been built for the purpose of studying the potentialities of manipulating two-dimensional patterns. The apparatus consists essentially of a flying-spot scanner and a monitor or "slave" oscilloscope to view the results of the scan, connected as indicated in the block diagram, Fig. 1. The scanner employs negative feedback to obtain a more faithful response in the video signal.[2] The modification of the picture is accomplished by inserting a suitable electrical circuit modifier between the output of the phototube and the intensity grid of the slave cathode-ray tube.

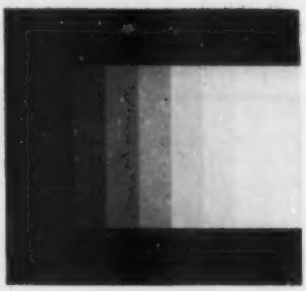

FIG. 2. Step wedge of density. Note the brightness contrast effect at the boundaries of the steps. Each step looks as if its shading varies across the step, although the shading is uniform. (This may be checked by covering the adjacent steps.)

The operations that may be pertinent to the problem of recognition and recollection, to some degree, appear to be independent of the orientation of the pattern. Isotropic Operations (that have no preferred direc-

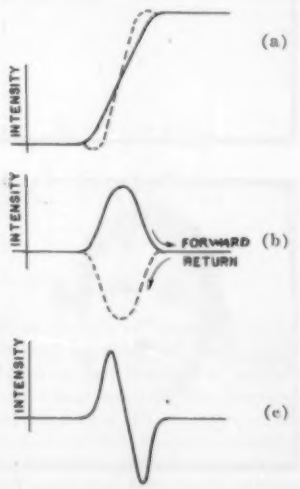

FIG. 3. (a) Signal obtained from scan of a step at transition (slightly defocused). (b) Differentiated signal of (a). (c) Second derivative of (a). *Note.* The sign is independent of the direction of scan.

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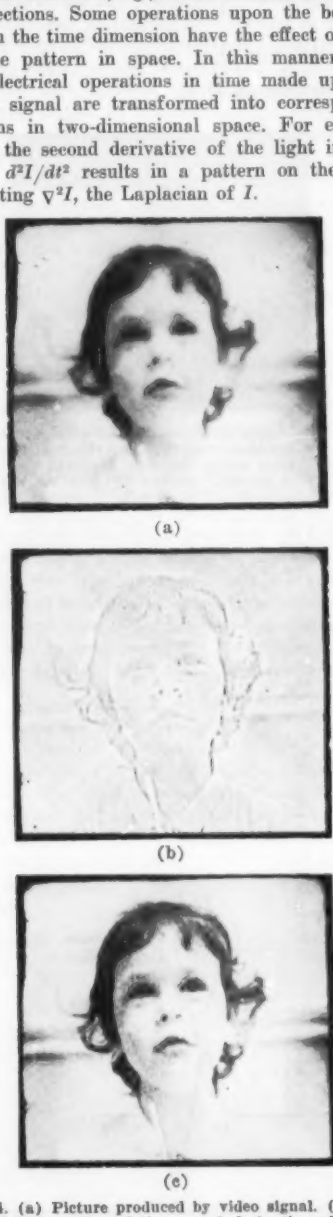
[2] A description of negative feedback applied to a flying-spot scanner has appeared in an article by R. Thelle and H. McGhee, "The Application of Negative Feedback to Flying Spot Scanners," in *J. Brit. Inst. Radio Engrs.* June, 1952.

tion) can be accomplished without resorting to special memory devices by using a scan that is isotropic in its properties.

The scan employed has the same velocity in two orthogonal directions, e.g., in both horizontal and vertical directions. Some operations upon the beam intensity in the time dimension have the effect of modifying the pattern in space. In this manner fairly simple electrical operations in time made upon the intensity signal are transformed into corresponding operations in two-dimensional space. For example, forming the second derivative of the light intensity in time, d^2I/dt^2 results in a pattern on the screen representing $\nabla^2 I$, the Laplacian of I.

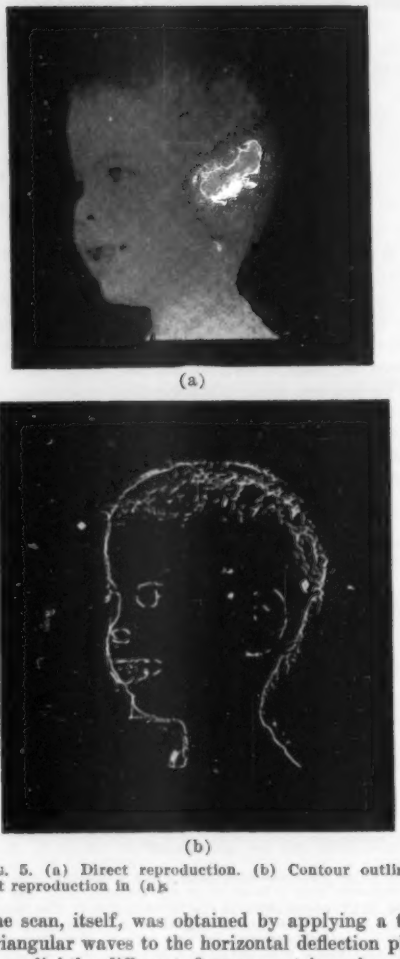


(a)

(b)

(c)

FIG. 4. (a) Picture produced by video signal. (b) Picture produced by negative of the second derivative of the video signal. (c) Picture produced by electrical additional of above signals.



(a)

(b)

FIG. 5. (a) Direct reproduction. (b) Contour outline of direct reproduction in (a).

The scan, itself, was obtained by applying a train of triangular waves to the horizontal deflection plates and a slightly different frequency triangular wave train to the vertical direction. Since the phase difference between the vertical and horizontal waves changes at a constant rate, the resulting rectangular Lissajous figure changes shape and covers the picture area in the period of the difference frequency. The scanning spot moves in each of the orthogonal directions of the rectangle at a constant velocity and thus the scan is isotropic.

The first process simulated with the equipment was that of the brightness contrast effect noted in the human eye. It can be observed by the reader in the step wedge (Fig. 2). Each step looks as if its shading varies across the step, although the shading was reproduced uniformly.[3] This effect is the enhancement of changes at boundaries or contours.

The contour enhancement was produced in the

[3] A similar accentuation occurs in photographic processes as the Eberhard effect.

monitor oscilloscope by forming the Laplacian of the density pattern and subtracting it from the directly reproduced pattern. The enhancement obtained is indicated for a one-dimensional pattern in the diagram of Fig. 3. The solid line in Fig. 3a shows the light amplitude, I, that would be obtained by scanning the area across the boundary between two of the steps in Fig. 2, both in the forward and the reverse directions. The solid line in Fig. 3b shows the first derivative obtained when scanning forward and the dotted line the opposite sign of differentiated light signal obtained when scanning in the reverse direction. Figure 3c shows the second derivative, whose sign is independent of the direction of scan. The dotted line in Fig. 3a shows the increased sharpness of transition obtained by subtracting a portion of the second derivative.

The effect of performing the same operation in two dimensions upon a photographic transparency is shown in the pictures of Fig. 4. Figure 4a is the direct reproduction of the picture as it appeared on a cathode-ray tube screen. Figure 4b is the negative of the second derivative as it appears on the same screen. Figure 4c shows the result of electrically adding the two signals. The definition of Fig. 4a was limited largely by the minimum scanning spot size available. The improvement in overall sharpness of the picture in Fig. 4c is readily apparent in the original photographs.

Other pictures have been degraded by increasing the scanning spot size or by reproducing the transparency in an enlarger by slightly defocusing the image. A similar improvement in sharpness was obtained in each of those cases. A mathematical analysis shows that this represents a first order restoration of a degraded function in cases when the original has been degraded by the processes mentioned above as well as by limited video pass band or by diffusion. This is a two-dimensional analogue of high-frequency compensation of an amplifier whose amplitude-frequency response decreases at higher frequencies.

This process has been repeated, or recycled, by scanning the reproduced pictures in the same manner as the originals. As expected, the direct reproduction is better when the improved picture (Fig. 4c) is used as the original. This tends to show that the two-dimensional analogue of preemphasis of the higher frequencies may be utilized to improve the reproduction of a picture by compensating for the properties of an imperfect system.

In addition to producing contour enhancement, the same equipment was used to produce a contour outlining effect, a method by which, it is believed, the visual memory extracts essential information from a pattern. By rectifying the signals shown in Fig. 3b and limiting them to a constant level, it is possible to outline the boundaries of the picture (resembling cartoon drawings) on the cathode-ray tube screen. A picture outlined in two dimensions is shown in Fig. 5. The picture shows an outline in white lines against a black background. However, it is easily possible to produce a white line picture by reversing the polarity of the rectifier.

The exploration of the properties of this system will proceed with attempts to determine the effects of other processes such as integration, modifications in the feedback circuit itself, and other matters. In addition to the potential practical values of the processes so far studied, the method of modifying two-dimensional patterns may be useful as an analogue computer for two-dimensional partial differential equations, and for studying the problem of the recognition and recollection of visual patterns.

Instrument Society of America Annual Conference and Exhibit

W. A. Wildhack[1]

National Bureau of Standards, Washington, D. C.

THE Instrument Society of America held its Eighth National Instrument Conference and Exhibit in Chicago during the week of September 21–25. More than 11,000 persons registered to attend the large exhibit held in the Hotel Sherman or to attend the sessions of the technical program held in the Hotel Morrison. As many as six sessions were held concurrently, with 37 sessions in all, and a total of nearly 100 papers presented. In addition to sessions arranged by technical committees of the Instrument Society of America, there were also sessions arranged by cooperating societies, including the American Society of Mechanical Engineers, the Institute of Radio Engineers, and the American Institute of Electrical Engineers. As in previous years, an interesting feature of the technical program was an "Instrument Maintenance Clinic" arranged for the instruction of plant and laboratory personnel in the operation and maintenance of various basic types of instruments. Manufacturers provided instructors and demonstrated equipment for this clinic, which lasted

[1] National Secretary, Instrument Society of America.

for three days before the opening of the regular conference, and for which nearly 500 persons registered.

A similar lecture and demonstration course on complex analytical instruments was designed to appeal particularly to research workers. Representatives of eight manufacturers repeated a three-hour discussion and demonstration lecture six times for small groups of 15 to 30 persons. The companies participating in the course, and the instruments demonstrated were:

Beckman Instruments, Inc.—analytical computers
Consolidated Engineering Co.—dynamic recording systems—amplifiers, pickups, and oscillographs
Gow-Mac Instrument Co.—thermal conductivity gas analysis
Minneapolis-Honeywell Regulator Co.—analytical application of recorders
North American Philips Company—x-ray fluorescence spectograph
Process Controls, Div. of Baird Associates—non-dispersion infrared analyzers
General Electric Company—dielectric constant and turbidity
Perkin-Elmer Corporation — dispersion infrared analyzers for the laboratory and plant

Reflecting the large percentage of industrial interest in the conference, the sessions on Instrumentation for Production Processes were heavily attended. Papers were given on "Instrumentation for Statistical Quality Control," "Segmental Recorders," "Specific Gravity Measurements," "Dynamic Analysis of Heat Exchanger Systems," "Pneumatic Multiplying and Process Control," "Human Engineering in Power Plant Instrumentation," a "Flow Controller," a "Liquid Metal Magnetic Flowmeter," "Instrumentation for Radiochemical Processing-Recovery of Iodine 131," a "Catalytic Hydrogen Gas Analyzer," and a "Carbon Monoxide Gas Analyzer." The sessions on testing instrumentation were also popular. An overflow audience gathered to hear F. G. Tatnall's entertaining history of the development, performance, and application of the bonded-wire strain gages, and other more detailed papers relating to strain gaging.

There were several papers relating to aeronautical instrumentation, to geophysical instrumentation, instrumentation for transportation, and three sessions of papers on instrumentation for biology and medicine. A selection of titles indicates the range of the papers of special biological interest: "Techniques of Micro Analysis," "Recording Oximeters," "Camera Design for Radio Micrography," "Electro Magnetic Flowmeter in Industry and Biology," "Instrumentation for Vectorcardiography," "Apparatus for the Quantitation of Biological and Other Data by Photoelectric Measurement of Areas," "Measurement in Biology."

The American Society of Mechanical Engineers sponsored a symposium on Production Weighing and Control, and a number of devices for automatically determining the mass or weight of granular or liquid materials was exhibited. One of these indicates the average mass flow of granular materials from a measurement of the torque required to drive a constant speed a horizontal rotating plate on which radial guide vanes whirl the material continually outward as it is allowed to drop onto the center of the plate.

Preprints of most of the papers were available, and the complete volume of the *Proceedings* will be published within a few months.

The exhibits of industrial and scientific instruments, components, and related devices occupied 35,000 square feet on various floors, halls, rooms, nooks and crannies in the Hotel Sherman, which was somewhat cramped already because of remodelling operations in the hotel lobby. However, a persevering visitor interested in a specific exhibit could eventually locate it with the aid of a map of the exhibit area and a descriptive list of exhibits in a 48-page program and exhibit guide supplied to all registrants.

With more than 200 manufacturers exhibiting, it appears that only the cities with the largest exhibit facilities will be able to play host to the Instrument Society in future years. It is planned that next year's conference, to be held in Philadelphia, will be international in character, and will be called the First International Instrument Congress and Exposition. Porter Hart, President of the Society, reported at the annual meeting that he and Richard Rimbach, Exhibit Manager, had toured the continent this summer to stimulate interest in attendance and participation in the international meeting next year. For future years, the tentative locations are: Los Angeles in 1955, followed by Detroit, New York, and Cleveland.

The only nonindustrial technical exhibit was that from the National Bureau of Standards. In previous years other government agencies have exhibited instrument developments of considerable interest. It is recognized that it would be highly desirable to have much more space devoted to the instrument developments of universities and nonprofit institutions, as a valuable adjunct to the educational work of the Society. It is hoped that many such organizations will have exhibits in the International Exposition at Convention Hall in Philadelphia, September 14–24, 1954. Other technical societies and organizations are invited by the ISA to hold joint meetings and exhibits on measurements in their special fields at that time.

Instrumentation is one facet of science which is common to all technical fields, and it is therefore both appropriate and sensible that the Instrument Society cooperate with other scientific and technical groups in joint meetings devoted to measurements and instruments of common interest. Together with the Institute of Aeronautical Sciences, the American Institute of Electrical Engineers, and the Institute of Radio Engineers, the ISA sponsored a National Telemetering Conference in Chicago last May; 250 persons attended the 3-day conference. Telemetering and equipment for data reduction were displayed by 15 manufacturers. The Telemetering Conference will be repeated next year. Another cooperative conference (AIEE, IRE, ISA) on Electronic Instrumentation and Nucleonics in

Medicine will be held in New York, November 19 and 20, 1953 (SCIENCE, p. 3, Oct. 16).

The membership of the Instrument Society is drawn as much from the users as from the manufacturers of instruments. Industrial firms, whose business depends on the efficient performance of modern instruments, especially those in the chemical, petroleum, utilities, and other process industries, are particularly interested in the activities of the Society and the work of the Society committees concerned with recommended practices for instrument specifications, installation, and standardization. Corporate membership is now available to corporations and organizations interested in the work of the Society, with dues of $250 per year. Manufacturers who exhibit at the annual conference are to be given corporate membership at no additional cost.

Officers of the Society for 1954 will be:

President, W. A. Wildhack, National Bureau of Standards, Washington, D. C.

Vice-Presidents, Warren H. Brand, Carbide and Carbon Chemicals Co., Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Delmas C. Little, Army Medical Research Laboratories, Fort Knox, Kentucky.

Axel H. Petersen, Mellon Institute, Pittsburgh, Pa.

Hans B. Freeman, Economy Equipment Co., St. Louis, Mo.

Secretary, Robert Sheen, Milton Roy Co., Philadelphia, Pa.

Treasurer, J. T. Vollbrecht, Energy Control Co., New York.

The Society Manager is P. V. Jones, and the Exhibit Manager is Richard Rimbach. Society headquarters are at 1319 Allegheny Avenue, Pittsburgh 33, Pa.

At the annual meeting of the Council, the governing body of the Society, approval was given to a proposal recommended by the Executive Board that the Society undertake the publication of its own journal within the next year. Thus, there will be available a more adequate vehicle for carrying the news of the Society and its activities, as well as a larger number of technical papers than the Society can publish in the present Journal of the ISA as a small section of the magazine *Instruments*. Prospective authors are urged to submit titles and abstracts for next year's conference, or for the new *ISA Journal*, as soon as possible, to permit adequate time for editorial review by appropriate committees, and for preprinting.

All readers are cordially invited to plan to attend next year's conference and exhibit in Philadelphia, to attend meetings of any of the 66 Sections of ISA throughout the country, and to affiliate with the Society if their work or interests require that they keep abreast of the broad and expanding field of instrumentation in their own branch of science or industry.

News and Notes

Fifth Annual Oak Ridge Summer Symposium

THE Oak Ridge Summer Symposium was held this year August 24–29, and was devoted to the subject, "Topics of Modern Physics." These summer symposia are offered jointly by the Oak Ridge National Laboratory and the Oak Ridge Institute of Nuclear Studies and are intended to provide a broad view of modern developments in various scientific fields. An attempt is made to arrange a program at each symposium with a broader coverage, both in subject matter and period of time, than is normally provided in meetings of professional societies. The symposia are scheduled each year at the end of the summer so as to coincide as nearly as possible with the period following the close of summer school sessions. The first symposia were devoted consecutively to the subjects of physics, chemistry, nuclear engineering, and the use of radioactive isotopes in agricultural research. Thus the symposium this year, in returning to the consideration of topics in modern physics, initiated a new cycle of annual offerings.

The total registration for the symposium was 248, of which 175 were local and 73 were from outside Oak Ridge. Among the latter, 36 universities and 25 states were represented. Two major fields of recent research in physics were covered in the symposium; namely, ultra-high energy particle phenomena and developments in spectroscopy throughout the range of the electromagnetic spectrum.

J. Steinberger of Columbia University presented a series of four lectures on mesons. Research on π-mesons was reviewed historically and the key experiments were described in some detail. Special emphasis was given to the concept of isotopic spin and the consequences of charge independence in nuclear interactions. The final lecture consisted of a brief review of experimental evidence relating to higher mass mesons and V-particles.

The remaining lectures in the field of ultra-high energy phenomena were given by M. S. Livingston of Massachusetts Institute of Technology. In his first lecture he described a detailed design, which has recently been completed by a group at Cambridge working

under his leadership, for a 15-Bev proton synchroton utilizing the principle of alternating magnetic gradient focusing. His second lecture consisted of the description of the operating characteristics of the Brookhaven cosmotron and the review of recent unpublished results obtained with it. In particular, the indicated trends of the π^+ and π^- cross sections on protons up to 1.5 Bev were shown, and recent cloud chamber studies of V-particles were described.

Recent advances in spectroscopy throughout the electromagnetic spectrum were covered in a large number of papers of considerable variety and interest. W. Gordy of Duke University described a number of recent advances in microwave spectroscopy and gave special attention to transitions between Zeeman components in electronic semiconductors and other solids, Λ-doublets arising from electronic angular momentum in diatomic free radicals, and the successful extension of microwave spectroscopy to the one-millimeter wavelength region, which has recently been achieved at Duke. The significance of this last development, which can use exceedingly small gas volumes, for microwave spectroscopy with radioactive isotopes was pointed out. In a parallel paper, Ralph Livingston of Oak Ridge National Laboratory described his work on pure quadrupole spectra in solids in the microwave region; of especial interest was the large body of information on solid state structures that is obtainable from symmetry properties of the electrical field gradient in single crystals as revealed by the Zeeman effect on these spectra. The whole range of developments in infrared spectroscopy during the past fifteen years was surveyed by A. H. Nielsen of the University of Tennessee. Particular attention was given to the extensive developments in the new infrared sources, detectors, optical materials, and recording spectrometers, which have taken place during this period.

Spectroscopic developments in the visible region of the spectrum were covered in two papers. The first, by J. R. McNally, Jr., of Oak Ridge National Laboratory, was concerned with a variety of results on nuclear spins and magnetic and quadrupole moments now obtainable with high-resolution spectroscopy of hyperfine structures. The second paper, by G. R. Harrison of Massachusetts Institute of Technology, was on the subject of echelle spectroscopy. The theory of the echelle was described in some detail, and construction of echelle spectrographic instruments and the spectrographs obtained with them were shown by lantern slides. Of especial interest was the neat manner in which the instrument would record a broad prism spectrograph and simultaneously record on the same plate narrow segments of this spectrum spread out in high resolution by the echelle at right angles to the corresponding positions of the main spectrograph.

For the x-ray and gamma-ray region of the electromagnetic spectrum, J. W. M. DuMond of California Institute of Technology gave two lectures on the bent-quartz crystal focusing spectrometers which he has developed. Everyone in attendance at the symposium was thrilled by the achievement represented in the construction of these instruments and the remarkable precision obtainable with them. The first instrument that he described places the gamma-ray source at the focus of the crystal and uses a scintillation counter detector in a fixed position behind the crystal. The other spectrometer reverses these positions and records the gamma-ray spectrum on a photographic film placed in the focal plane of the crystal. A. Abragam of the Centre d'Études Nucleaires de Saclay, France, discussed the theoretical formulation of the problem of angular correlations of successive gamma rays from nuclear transitions, particularly as they are affected by crystalline electrical fields through quadrupole interactions and also by externally applied magnetic fields. T. A. Welton of Oak Ridge National Laboratory discussed quantum electrodynamics in two lectures with specific attention to the Lamb shift and the new covariant formalism of Schwinger, Feynman, and Dyson.

In a very interesting paper on a subject lying outside the domain of these two major fields, C. H. Eckart of the University of California Marine Physical Laboratory described a new approach to the theory of steady turbulence in fluids that he has developed, based on replacing time averages of velocity components with ensemble averages in a manner entirely analogous to the corresponding procedure followed in statistical mechanics. In an evening lecture open to the public of Oak Ridge as well as to the symposium participants, C. J. Craven of the University of Tennessee reviewed the remarkable and interesting results now being obtained in the new field of radio astronomy.

In addition to the formal symposium sessions, a tour of the reactors and other facilities at Oak Ridge National Laboratory was arranged for the first afternoon.

WILLIAM G. POLLARD
Oak Ridge Institute of Nuclear Studies
Oak Ridge, Tennessee [2]

Scientists in the News

John M. Beal, Chairman of the Botany Department at the University of Chicago since 1949 and a member of the faculty since 1929, has retired. He is succeeded by **Charles E. Olmsted,** professor in the same department. Dr. Olmsted's interests lie chiefly in the field of physiological ecology. He has worked especially on the effects of photoperiodism and temperature on various grasses.

Dr. Beal received a B.S. from North Carolina State College in 1911, an M.S. from Mississippi State College in 1913, and a Ph.D. from the University of Wisconsin in 1927. His recent research has included studies of the effects of C^{14} on the genetic characteristics of plants.

During his tenure as department chairman Dr. Beal made cooperative arrangements for research with neighboring institutions, such as the plan whereby

graduate students in the Botany Department may pursue research on systematic and ethnological botany at the Chicago Natural History Museum. Besides using the museum's facilities, they benefit from the direction and advice of members of the museum staff.

Hwai-Sze Fang, Professor of Physiology at the National Taiwan University, has spent the last six months studying aviation medicine in the Department of Physiology at the Ohio State University Medical School. After attending the 19th International Physiological Congress, he has returned to Taiwan.

Willis E. Lamb of Stanford University will be in residence at Harvard University during the fall term and will lecture on microwave spectroscopy and quantum mechanics. Professors **Enrico Fermi,** University of Chicago, and **Freeman Dyson,** Institute for Advanced Study, Princeton, will be in residence for shorter periods of time, each giving colloquium talks and a series of four lectures.

Duncan E. Macdonald, Director of the Boston University Physical Research Laboratories since 1946, has been appointed Dean of the Graduate School. He will retain his directorship of the Physical Research Laboratories, but will move his headquarters to the Graduate School. The Laboratories are noted for their work, conducted under U.S. Air Force sponsorship, in the field of aerial photography.

William Frederick Meggers, Chief of the Spectroscopy Section at the National Bureau of Standards, has received an Elliott Cresson Medal from The Franklin Institute, Philadelphia, "for his monumental work throughout four decades in the field of Spectroscopy—work which has exhibited a high degree of diligence, consistent accuracy and scientific responsibility, work which has produced much of the reliable experimental data upon which rests our present detailed knowledge of the electronic structures of scores of elements."

In the Biology Department of the Western Illinois State College, Macomb, **R. Maurice Myers** has been appointed Head of the Department to succeed **Mary A. Bennett,** who is retiring, and **Howard F. Young,** formerly Assistant Professor of Zoology at the University of Arkansas, has been made an Associate Professor.

George Cheney Newton, Jr., Associate Director, Servomechanism Laboratory, Massachusetts Institute of Technology, has been awarded the Louis E. Levy Medal by The Franklin Institute, Philadelphia, for his paper, "Compensation of Feedback-Control Systems."

Arnold W. Ravin, postdoctoral fellow of the U.S. Public Health Service in the laboratories of Boris Ephrussi and Harriett Ephrussi-Taylor at the University of Paris, has been appointed Instructor in Biology at the University of Rochester. Dr. Ravin will continue his research on bacterial transformation, and will take a major role in developing the basic elementary biology course.

Warren E. Wilson, formerly President of the South Dakota School of Mines and Technology, has been appointed Director of the Engineering Sciences Division, Office of Ordnance Research. OOR is the administrative office which supervises the $4,000,000 program of basic research sponsored by the Ordnance Corps, U.S. Army. It is located on the campus of Duke University. Dr. Wilson succeeds **Newman A. Hall,** who has returned to his academic duties as Head of the Heat Power Division, Department of Mechanical Engineering, University of Minnesota.

Education

The **A. F. Davis Welding Library,** located at **The Ohio State University** in Columbus, has recently acquired over 2200 abstracts of British welding patents; these are classified in the usual manner. The library was established in 1942 by A. F. Davis, Vice President and Secretary of The Lincoln Electric Company, Cleveland. Ohio State is the only university in this country that offers a five-year course in welding engineering leading to the degree of Bachelor of Welding Engineering.

At **Harvard University** a new fireproof, air-conditioned botanical building is being constructed and will be ready for occupancy early in 1954. This building, which will be adjacent to the north wing of the Museum of Comparative Zoology and the Farlow Library and Herbarium, is designed to house the Gray Herbarium and Library, a major part of the Library and Herbarium of the Arnold Arboretum, the Orchid Herbarium of Oakes Ames, and Harvard's paleobotanical collections. By bringing these collections together in close physical proximity to the Botanical Museum, the Farlow Library and Herbarium, the library of the Museum of Comparative Zoology, and the Biological Laboratories, the work of staff members and graduate students will be stimulated and facilitated.

An evening course in **industrial optics,** designed to be of value to engineers and technicians seeking advanced knowledge in this specialized field, is being offered this fall by the **Illinois Institute of Technology** in cooperation with optical firms in the Chicago area and with the Optical Society of Chicago.

The course will have weekly sessions, conducted by specialists from industry and from the Institute, beginning Oct. 13 and continuing through Feb. 2, 1954. The following areas will be covered: colorimetry and photometry; geometrical optics; electron optics; and laboratory practice and instruments. If the new course is successful, it may be the forerunner to the establishment of a complete curriculum in optical engineering at IIT.

The New York Academy of Medicine is sponsoring its 19th annual series of **Lectures to the Laity** under

the general heading, "The Reciprocal Relations Between Medicine and the Other Disciplines." The schedule for the first three lectures is as follows:

Nov. 4, "The Application of Physics to Medicine." Norbert Wiener, Professor of Mathematics, Massachusetts Institute of Technology.

Nov. 18, "The Relation of Electrochemistry to Medicine." Theodore Shedlovsky, Associate Member of The Rockefeller Institute.

Dec. 2, "The Practice of Psychiatry—Past and Present." Clarence P. Oberndorf, Clinical Professor of Psychiatry, Columbia University.

Grants and Fellowships

The **Life Insurance Medical Research Fund** invites faculty members to nominate candidates for 1954–55 predoctoral fellowships for research in the medical sciences, preferably in the cardiovascular field. *Nomination deadline is Nov. 30.* Open to those who will have completed a year or more of work in a medical or graduate school and can devote most of their time to research, stipends range from $2,000 to $2,400. Further information is obtainable from the Scientific Director of the Fund whose address is 345 E. 46 St., New York 17, N.Y.

The **National Research Council** of the National Academy of Sciences is now accepting applications for the following postdoctoral and predoctoral fellowships that provide special opportunities for advanced study and training in fundamental research in the natural sciences for the 1954–55 academic year.

National Research Council Postdoctoral Fellowships in the Natural Sciences. Supported by the Rockefeller Foundation, these are intended to promote the training of investigators in basic research in the natural sciences, primarily in educational and research institutions of the United States and in exceptional cases in institutions abroad. These fellowships are open to citizens of the United States and Canada. A fellowship applicant must choose an institution other than that at which he has had most of his academic training. Fellowships are available in the fields of Agriculture, Anthropology, Astronomy, Biochemistry, Biophysics, Botany, Chemistry, Forestry, Geography, Geology, Geophysics, Mathematics, Paleontology, Physical Geography, Physics, Psychology, and Zoology.

Lilly Research Laboratories Postdoctoral Fellowships in the Natural Sciences. These fellowships are available in those sciences fundamental to the understanding of biological phenomena, especially in the borderline fields between Chemistry, Biology, and Physics. Applicants must produce evidence of training in one of the natural sciences equivalent to that represented by the Ph.D. or Sc.D. degree and must have demonstrated superior ability for creative research. A fellowship applicant must choose an institution other than that at which he has had most of his academic training. These fellowships are open only to citizens of the United States.

Merck Senior Postdoctoral Fellowships in the Natural Sciences. These Senior Fellowships are awarded for the purpose of giving advanced education, training, and development to individuals who have demonstrated marked ability in research in the physical, chemical, or biological sciences and who wish to broaden their fields of investigational activity by acquiring some familiarity with another area. A fellowship applicant must choose an institution other than that at which he has had most of his academic training. Applicants must produce evidence of training in Physics, Chemistry, Biology, or preclinical medical sciences equivalent to that represented by the Ph.D. degree, and must have had at least three years of postdoctoral professional experience in their major field, including not more than one year of fellowship work. These fellowships, with no age restriction, are open only to citizens of the United States.

RCA Predoctoral Fellowships in Electronics. These are offered to give special graduate training and experience to young men and women in the general field of electronics, either as a branch of Electrical Engineering or as a part of the general field of Physics. Applicants must have demonstrated ability and aptitude for advanced work and must have had training in electronics equivalent to that represented by one year beyond the bachelor's degree in a university of recognized merit in this field. It is understood that the training for the bachelor's degree may come from the general area of Electrical Engineering or Physics. Applicants must be citizens of the United States and fellowships will be awarded only for study and research in the United States.

Applications for any of these programs must be postmarked on or before Dec. 10. Fellowships are awarded in the late winter or early spring. Complete details and application blanks may be obtained from the Fellowship Office, National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C.

Since January, 1953, **Sharp & Dohme**, Division of Merck & Co., Inc., has made grants totalling $45,910 to 13 institutions scattered throughout the United States and Canada.

In the Laboratories

The plant pest control offices of **The Connecticut Agricultural Experiment Station** have been transferred from Danielson, where they have been located for the past 40 years, to the Station's Tobacco Laboratory at Windsor.

The Texas Division of **The Dow Chemical Company** is dedicating a new $2,600,000 research center to William Reed Veazey, recently retired director and research consultant. The new building has 69,000 sq ft of space to house the Division's organic, chemical engineering, and electrochemical research, as well as the analytical laboratory, research administrative offices, a patent office, and a library.

The General Electric Company plans to construct a $1,800,000 combustion laboratory in Schenectady. The story and a half building will provide 14,200 sq ft of floor space, and is scheduled for completion in late 1954. It will be divided into five main working areas: an air compressor and preheater room; a combustion test cell for evaluating new ideas on the theoretical and practical aspects of combustion; a turbine bucket study area; a high-speed test pit; and shock wave experimental facilities. The new laboratory will be devoted chiefly to basic scientific studies in order to obtain information about the exact chemical and thermal nature of combustion.

A new **method for counting virus particles** has greatly aided cancer research at Duke University. The new system, developed by Gordon Sharp of the Duke Medical School, saves scientists months of work. For example, investigations on 105 virus-produced cancers in chickens which formerly would have required two months can now be completed in approximately 20 minutes.

In the new method a sample of unpurified blood plasma—only 1/30 of a drop being needed—is spun down in a centrifuge, so as to separate out the virus particles, which adhere to agar at the bottom of the test tube. The virus particles are then transferred from the agar to a liquid coating of collodion and placed under an electron microscope where they are counted over a given area. By multiplying this count by the magnifying power of the instrument, the scientist learns how many virus particles are in the sample.

A machine that automatically scans photographic plates of the heavens, identifies individual stars, and punches their positions on IBM cards has just gone into operation at the **Watson Scientific Computing Laboratory.** Prof. Wallace J. Eckert, Director of the laboratory, which is jointly operated by Columbia University and the International Business Machines Corp., headed a team of astronomers and engineers that has been working on the project for six years. The unique "star factory" makes as many measurements in one day as a highly trained person can in a week, and with four times the accuracy.

Photographic plates 17 inches square, which contain the images of from 300 to 450 stars each, are placed on the adjustable plate holder of the measuring device. From IBM cards the approximate location of individual stars, obtained from a previous star catalogue, is transmitted to selsyn motors. These motors move the appropriate image in front of a very sensitive photoelectric eye, and the eye measures its exact position to within tenths of a micron. The position is then relayed back to the same card and punched on it. In order to relate positions measured on the plate to the true positions in the sky, elaborate computations are necessary. Electronic calculators can do this work automatically, using the punched cards from the "star factory." The resulting true positions can then be printed electrically and reproduced photographically. This final step in mechanizing a once arduous and time-consuming part of astronomy will provide increasing amounts of data to astronomical theorists. Some of the problems solved in building the "star factory" will also be applicable to the automatic operation of machine tools and to manufacturing plants.

Miscellaneous

A major study of the neurological disorder called **amyotrophic lateral sclerosis** has just been initiated on Guam, where it has been highly prevalent for generations and where the character of the population and the environment make possible an analysis of its causes. This was recently pointed out by Donald R. Koerner, Navy physician stationed for some years in Guam. The U.S. Public Health Service, the Navy Bureau of Medicine and Surgery, and the Department of the Interior are participating in the two-month project, which will be headed by Leonard T. Kurland, Chief Epidemiologist of the National Institute of Neurological Diseases and Blindness, who left for Guam in September. Donald Mulder, U.S. Navy, and K. K. Waering and S. Tillema of the Government of Guam will cooperate in the investigation.

Amyotrophic lateral sclerosis is popularly recalled as the illness responsible for Lou Gehrig's death. It is a degenerative disease of the nervous system marked by demyelination of the nerve fibers, and seems to manifest itself in two types: a slow progressive type primarily paralyzing the muscles of the hands and arms (eventually affecting other organs as well), and a more rapidly progressive type in which shoulders, neck, tongue, lips, palate, and pharynx are initially involved and paralyzed. There is no treatment for the disorder, and its cause is still unknown. Its incidence in the United States is also unknown, but most neurologists agree that there are approximately 1500 to 2500 cases yearly, with the average case having about three years to live from the time of onset. The disease occurs most frequently between the ages of thirty and fifty-five.

The new research group hopes to determine whether or not the disease is as prevalent on Guam as believed, if it is exactly similar to the disorder as it is known elsewhere, and finally, just what the possible causes may be—whether genetic, traumatic, infectious, economic, nutritional, or otherwise.

Poland has received from Czechoslovakia the original manuscript of the major work of the great Polish astronomer, Nicholas Copernicus. Known in Latin as ***De Revolutionibus Orbium Coelestium Libri VI*** (Concerning the Revolutions of the Heavenly Spheres), the document which altered man's concept of the universe had been in Czechoslovakia for the last 400 years. It is now in the National Museum in Warsaw. First to see the manuscript after its return to Poland were the participants in the special session held by the Polish Academy of Sciences to commemorate the 410th anniversary of Copernicus' death. (The 400th anniversary could not be observed because of the occupation of Poland.)

Technical Papers

The ER-55 Projector for Aerial Mapping[1]

Russell K. Bean

U. S. Geological Survey, Washington, D. C.

For many a scientific or engineering venture of today, one of the most vital prerequisites is accurate topographic maps. The ever increasing demand for more and better maps has placed a heavy burden on our mapmaking facilities. Only by the development and application of new mapping techniques based on aerial photography have we been able to keep pace with the growing need. The story of the development of photogrammetry, the science of obtaining reliable measurements by means of photography, is documented in very extensive literature covering this field.[2] A single new development in the field of photogrammetry, the ER-55 projector, is described here.

Many instruments have been developed for converting the data available on aerial photographs to topographic maps. These instruments range from simple inexpensive gadgets of limited application to complicated and costly machines capable of producing maps of the highest precision. In the United States, the principal device for compiling topographic maps

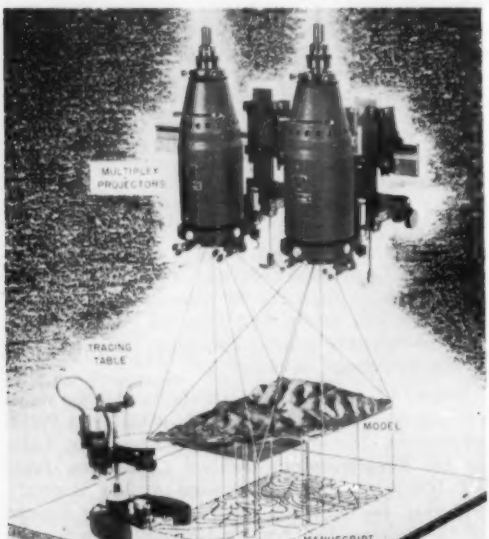


FIG. 1. Principle of the multiplex.

[1] Adapted from a paper presented at the 19th Annual Meeting, American Society of Photogrammetry, January 14, 1953.
[2] See bibliography in *Manual of Photogrammetry*, American Society of Photogrammetry, 1952.

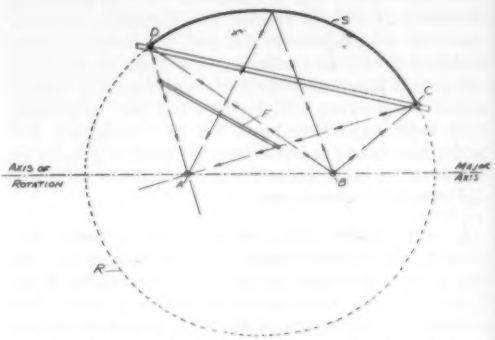


FIG. 2. Prolate ellipsoid of resolution showing paths of light rays.

from aerial photographs has been the multiplex projector, a relatively simple instrument for stereoscopic plotting of maps by the direct double-projection method (Fig. 1). Details of the operation of this instrument are available in the *Manual of Photogrammetry* published in 1952 by the American Society of Photogrammetry.

The ER-55 projector is a new kind of photogrammetric projector for stereoplotting by the direct double-projection method. It has a number of advantages over the multiplex projector. The principal distinctive feature of the instrument is that the light for projecting the image is condensed by an ellipsoidal reflector instead of by a condensing lens system. The designation "ER-55" is derived from two of the physical properties of the projector: "ER" signifies "ellipsoidal reflector," and the principal distance of the projector is 55 mm.

The development of the ER-55 projector was planned and carried out in accordance with three guiding principles:

1) It was recognized that there are certain exploitable advantages in double-projection instruments, such as the multiplex, as compared to the highly complex instruments of the optical-train type. These advantages are: low initial cost; low maintenance costs; ease of operation, requiring brief training; minimum of moving parts, including a stationary light source; direct anaglyphic viewing of projected images; and rapid stereotriangulation.

2) It was recognized that previous instruments of this type had certain disadvantages, namely, loss of resolution due to the process of greatly reducing the aerial negative to a small diapositive in a diapositive printer; poor illumination; limit of permissible magnification imposed by resolution and illumination limits; and aberrations of the condensing lens system.

3) It was recognized that if a practical instrument could be developed retaining the advantages of the simple double-projection instruments while overcom-

ing previous disadvantages, the product would be one of great usefulness, efficiency, and economy for both vertical and low-oblique photography.

The principle of the new projector is based on a well-known property of a concave mirror conforming to a prolate ellipsoid of revolution, (Fig. 2); light rays emanating from a light source located at one focus of the ellipsoid are directed by reflection toward the second focus. The main components of the projector, namely the light source, the reflecting surface, and the projection lens, are so configurated and oriented as to exploit this property. It will be noted that the reflector is unsymmetrically positioned with respect to the axes.

A diapositive plate, *F*, is suitably positioned in the system at the appropriate principal distance from the lens. Light rays emanate from the light source at one focus, *B*, of the ellipsoid of revolution, pass through a red or blue filter and strike the ellipsoidal reflecting surface, *S*. The rays are then reflected so that they pass through first the diapositive, *F*, then the projection lens, *A*, at the second focus, and thence to the platen of a plotting table. This system results in the projection of the image of the photography in a color corresponding to the color of the filter. From this point on, the operation is the same as that of multiplex-type instruments.

A vital feature of the system is that because of its unsymmetrical configuration no light rays pass directly from the light source to the lens through the diapositive; as a result, there is no "hot spot" caused by direct light rays, and the light distribution is relatively even. The reflecting surface consists essentially of only that portion of a complete ellipsoid required for the reflection of the bundle of rays which encompasses the entire area of the diapositive, with the lens as a perspective center for the reflected rays. This surface is represented by *S*, extending from *C* to *D*.

The primary problem in designing an ellipsoidal-reflector projector that would fulfill the desired objectives was to determine suitable values for the following interrelated factors: size of diapositive, principal distance and projection distance of the projector, focal length of the projection lens, and size and shape of the ellipsoid. Figure 3 shows the design finally adopted.

The final design, arrived at after several trial calculations, represents the optimum combination of the interrelated factor—the diapositive size being increased to yield better resolution, while still keeping the instrument size within practical working limits. Principal distance and optimum projection distance of the projector were selected keeping in mind the desired plotting scales as well as the projector spacing on the supporting frame.

The size and shape of the ellipsoid were selected by determining the most compact physical arrangement that would accommodate the lens placed at one focus, the light source at the other focus, and the diapositive plate properly placed at the correct principal distance

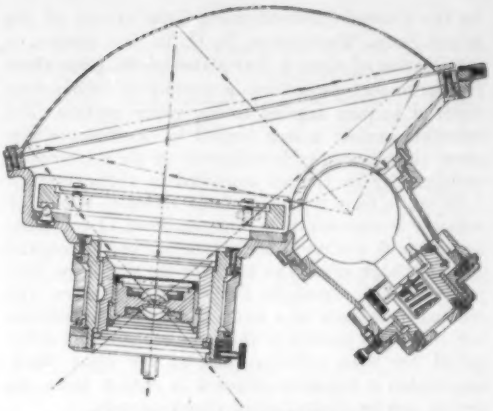


FIG. 3. Cross section of ER-55 projector.

from the lens. The focal separation and the length of the major axis were chosen to give the smallest ellipsoid that would physically accommodate the parts and provide the necessary clearances.

A companion design and development problem, carried on concurrently with the development of the ER-55 projectors, has been the production of a highly efficient diapositive printer designed for the specific purpose of making diapositive plates for these projectors. The new printer, recently completed in prototype form, is capable of capturing and transferring to the diapositive practically all of the detail appearing on the negative. This printer was constructed by the Geological Survey with optical parts, including a virtually distortion-free high-resolution lens and an aspheric correction plate, furnished by Wild of Switzerland.

The difficulties of developing the ER-55 projector were by no means confined to problems of design. There remained some formidable manufacturing problems before the first pair of projectors could be delivered. The most difficult of the manufacturing problems was the production of the precise ellipsoidal glass blank to be used as the pattern about which the reflecting surface is electroformed. The rough blank was made of high-quality glass by the Corning Glass Works. The first blank to be produced successfully was delivered by Corning to J. W. Fecker, Inc., of Pittsburgh, Pa., who had the contract for finishing and polishing the ellipsoid to its final precise dimensions. The Fecker organization designed and built a machine solely for the grinding and polishing operations required on this job. The hazardous operation of reducing the blank to the precise dimensions required was successfully completed after many weeks of painstaking effort. A testing apparatus, especially designed for the purpose, was then set up for inspecting the finished blank for conformance to specifications.

The electroforming operation for producing the mirror from the glass blank was done under contract

by the General Electroforming Laboratories of the Silver Shop, Washington, D. C. In this process, a thin coating of silver is first plated on the glass blank for permanent protection. A coating of nonbonding material is then applied to the entire surface. The reflecting surface is then formed by electrodepositing silver (or other suitable material) on the nonbonding coating. Copper is next deposited to a thickness of 3/32 in., to form the body of the reflector. When the reflector is removed, it is thus composed of a copper backing with a silver reflecting surface on the concave side. Although silver was used for the prototype projectors as an expedient, the reflecting surface will eventually be made of a metal less subject to tarnishing. As only a portion of the complete ellipsoid is required for each reflector, and as the glass blank approaches a complete ellipsoid in extent, three reflectors can be electroformed simultaneously.

The Geological Survey is contemplating the utilization of the ER-55 projector in various ways.

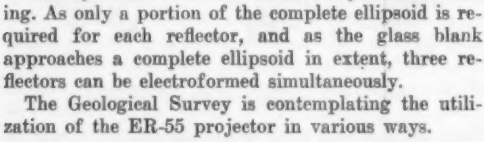


FIG. 4. Pair of ER-55 projectors mounted on standard multiplex supporting frame. The projectors are arranged for vertical photography.

For using vertical photography (see Fig. 4), ER-55 projectors can be mounted in pairs on a standard multiplex supporting frame. The main advantage of using the ER-55 projectors for mapping with vertical photography is that the area to be mapped can be photographed at higher altitudes as compared to multiplex flying, because of the improved illumination and resolution, and larger mapping scale. Since mapping costs generally decrease rapidly with an increase in flying height, the advantage is a substantial one.

The use of ER-55 projectors for compiling single-model convergent photography will provide, in addition to improved illumination and resolution and larger scale, all the inherent advantages of convergent photography.

Stereotriangulation of low-oblique photographic flights can be accomplished with a Twinplex plotter fitted with four twin ER-55 projectors. A simple swing adjustment applied to each projector-couple makes this instrument readily applicable to the bridging of either convergent or transverse low-oblique photography. The Geological Survey prototype Twinplex plotter is fitted with two twin ER-55 projector units. When completed four twin-projector units will be mounted on this instrument.

The ER-55 projector meets certain requirements, promises certain economies and constitutes a step forward in the field of simple double-projection plotters. It is expected that it will take its proper place with other photogrammetric instruments, each of which fills a certain need and is best adapted for the performance of certain jobs.

In addition to its use in stereoplotting instruments of the direct optical projection type, the principle of this invention can be used in other types of stereoplotting instruments and in enlarging or rectifying equipment. As pointed out in the patent application, the same principle can also be used in scientific fields other than photogrammetry. For example, an ellipsoidal-reflector system would provide brilliant illumination of a microscope slide. Or, such a system could be used in the reverse direction as a light gathering means for determining light values. In short, an unsymmetrical ellipsoidal-reflector system may prove advantageous whenever it is desired to concentrate light with the maximum efficiency and to obtain freedom from chromatic aberrations.

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A Note on the Lead Isotope Method of Age Determination

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Recently several papers have been published which attempt to interpret variations in the isotopic abundances of common leads. An important contribution was made in 1951 by Alpher and Herman (*1*) who showed that the observed lead abundances could be related approximately to the ages of lead minerals by simple mathematical formulas. They assigned dates to a number of analyzed lead ores and calculated the constants in these formulas by a least squares analysis. This calculation was later repeated by Collins, Russell, and Farquhar (*2*), who used data from additional lead samples of known age.

Russell, Farquhar, Cumming, and Wilson (*3*) have recently proposed a method whereby the variation in common lead abundances can be used for dating certain galena samples. A possible objection to the proposed method is that the mathematical formulas used will not be correct if the galenas used by Collins, Russell, and Farquhar for the original calibration have not been correctly dated. The purpose of this note is to demonstrate that common lead abundance-time expressions can be obtained without the use of dated samples.

TABLE 1

Source	Isotopic abundances ($Pb^{204}=1.00$)			Ages (in 10^9 yr)		Mean
	206	207	208	By Pb^{206} curve	By Pb^{208} curve	
Ivigtut, Greenland	14.85	14.94	35.07	1.91	1.75	1.83
Yellowknife Area, N.W.T., Canada *†	14.34	15.26	34.46	2.14	2.05	2.10
Horseshoe Island, Great Slave Lake, N.W.T., Canada	14.16	15.08	34.28	2.22	2.14	2.18
Phoenix Mine, Norseman, Western Australia	14.21	15.23	34.19	2.20	2.18	2.19
Borderland Mine, Busia, Eastern Province, Uganda†	14.05	15.10	34.24	2.27	2.16	2.22
Risks Mine, Kakamega, Kenya Colony†	14.05	15.05	34.21	2.27	2.17	2.22
Copperhead Mine, Bullfinch, Western Australia	14.19	14.92	33.80	2.21	2.38	2.30
Inguladhal, Chitaldrug District, Mysore State, India	14.17	14.74	33.80	2.22	2.38	2.30
Sioux Lookout, Ontario	14.05	14.92	33.85	2.27	2.35	2.31
Steep Rock Lake, Ontario†	13.94	14.83	33.75	2.32	2.40	2.36
Rosetta Mine, South Africa	12.65	14.27	32.78	2.85	2.87	2.86

* Average of results of four samples from Negus and Con Mines. The analyses were sufficiently similar to permit averaging.

† These isotopic analyses have not been published previously. We are grateful to R. W. Boyle, A. M. Macgregor, and J. P. Marble for making these samples available.

The equations of the abundance-time curves are (*2*):

$$x_m = a - \alpha V(e^{\lambda' t_m} - 1) \quad (1a)$$
$$y_m = b - V(e^{\lambda' t_m} - 1) \quad (1b)$$
$$z_m = c - W(e^{\lambda'' t_m} - 1) \quad (1c)$$

where x_m, y_m, z_m; a, b, c are the abundances relative to Pb^{204} of Pb^{206}, Pb^{207}, and Pb^{208} at times t_m and the present, respectively. V and W are the present relative abundances of U^{235} and Th^{232} with respect to Pb^{204}, α is the present ratio of U^{238} to U^{235}, and λ, λ', and λ'' are the decay constants of U^{238}, U^{235}, and Th^{232}.

The values for a, b, c, V, and W were originally found by a least squares method (*1, 2*). The data which are most likely to be in error are the ages of the samples, t_m. However, the values of a, b, and c will be affected but slightly by changes in t_m. This is confirmed by the fact that the values for a, b, and c from Alpher and Herman's paper, based on different data and calculated with an incorrect decay constant, are within 1½% of those found by Collins *et al.*

Furthermore, it is generally assumed that the failure of lead isotope abundances to fit the theoretical curves is caused by variations in the distribution of lead, uranium, and thorium since the solidification of the earth's crust. This would imply that the older lead samples should fit the theoretical curves more closely than the younger ones. It would therefore seem reasonable to use the data from older samples to estimate new values for V and W, while taking for a, b, and c the values found in (*2*).

Expressions for the abundance-time curves can be obtained from the older lead ores, without assigning ages to them. Since the method does not depend on the actual values of t_m, it is not affected by uncertainty in their values. From equations 1*a* and 1*b*

$$t_m = \frac{1}{\lambda}\log\left(1 + \frac{a - x_m}{\alpha V}\right) \quad (2a)$$

$$t_m = \frac{1}{\lambda'}\log\left(1 + \frac{b - y_m}{V}\right) \quad (2b)$$

Let δ_m be the difference of these two expressions for t_m and consider finding the value of V which minimizes $\Sigma\delta_m^2$. Let $\overline{V}$ be an approximate value for V and $\overline{\delta}_m$ the corresponding approximate value of δ_m. For $\overline{V}$ we have taken 0.0714, the value found for V in (*2*). If ΔV is the difference between $\overline{V}$ and the value which minimizes $\Sigma\delta_m^2$, then

$$\delta_m = \overline{\delta}_m + \left(\frac{\overline{\partial\delta}}{\partial V}\right)_m \Delta V$$

The value of ΔV is found to be

$$\Delta V = -\Sigma\overline{\delta}_m \left(\frac{\overline{\partial\delta}}{\partial V}\right)_m \Big/ \Sigma\left(\frac{\overline{\partial\delta}}{\partial V}\right)_m^2$$

The data used for the calculation are given in Table 1. About one-half of these are the results of new isotopic analyses carried out by the authors. All analyses were carried out at Toronto using the same 180° Nier type mass spectrometer. The results obtained for a calibration sample analyzed with this instrument are being published elsewhere (*3*). The following values (*2*) are used for the constants: $a = 18.45$; $b = 15.61$; $\lambda = 0.154 \times 10^{-9}(\text{yr})^{-1}$; $\lambda' = 0.980 \times 10^{-9}(\text{yr})^{-1}$; $\alpha = 139$. It is found that $\Delta V = 0.0043$, and hence $V = 0.0757$.

A new value for W may now be obtained by applying a least squares analysis to equation 1*c*, assuming c known (= 38.40) and taking $\lambda'' = 0.0499 \times 10^{-9}$ $(\text{yr})^{-1}$. We obtain

$$W = \Sigma(c - t_m)(e^{\lambda'' t_m} - 1)/\Sigma(e^{\lambda'' t_m} - 1)^2$$

The values for t_m are calculated from equation 2*a*, using the new value of V. The formula gives $W = 36.5$. The former value was $W = 38.2$.

The changes that these new values produce in the form of the curves are shown in Fig. 1; the new curves are solid. The difference is encouragingly small; for example, the upper limit to the age of the elements given by the intercept of the Pb^{207}/Pb^{204} curve with the time axis is changed only from 5.5×10^9 yr to 5.4×10^9 yr.

The ages obtained for the samples by fitting them to the Pb^{206}/Pb^{204} and Pb^{208}/Pb^{204} curves are given in Table 1. These appear to be in reasonable accord

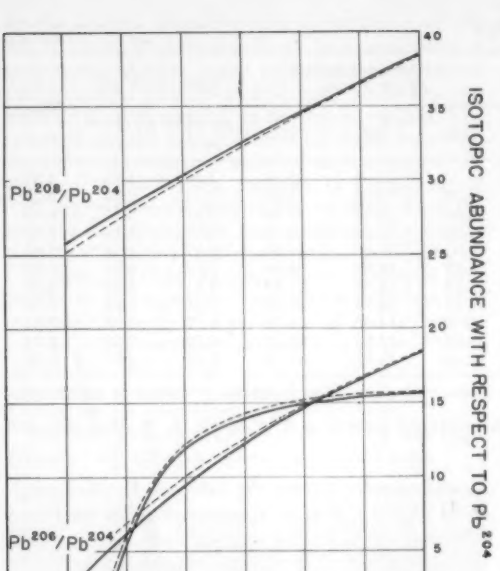

FIG. 1. Average lead isotope abundance-time curves. Broken curves after Collins *et al.* (2). Solid curves are those derived in this paper.

with each other and with ages obtained by other methods of geological dating. In Fig. 2 abundances of the lead samples are plotted against the mean ages. It is seen that they fit all three curves quite closely. This supports the hypothesis that the old leads should fit the curves fairly well.

In conclusion, the results above would seem to show that the uncertainties in the ages that have been assigned to common lead samples have not caused a very great error in the results obtained by Collins, Russell, and Farquhar.

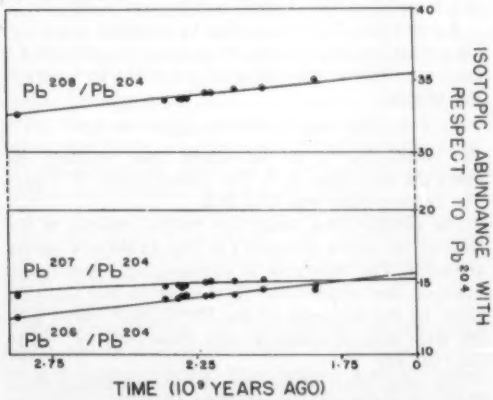

FIG. 2. Isotopic abundances of old leads fitted to the abundance-time curves.

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An Effective Safety Pipette[1]

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The increasing use of radioactive solutions, suspensions of viable microorganisms and other hazardous liquids has created a need for accurate transfer of these materials by pipette without exposure to the operator. Several remotely controlled pipettes (*1, 2*) have been designed to fulfill this need. In addition to these remotely controlled pipettes, many scientific supply houses furnish various devices labeled as "safety pipettes" to accomplish the same purpose. There are two serious difficulties with the available types of apparatus: (*a*) they are generally quite elaborate and expensive, and (*b*) the operator is unable to control the liquid in the pipette with any degree of accuracy. It is the purpose of this note to present a very simple and easily constructed piece of apparatus which eliminates the possibility of oral or cutaneous contamination of the operator when transferring toxic or hazardous liquids, yet it maintains complete and accurate delivery control.

The apparatus, as shown in Fig. 1, is constructed by sealing a piece of 5-mm OD glass tubing to a piece of 6-mm OD tubing in a T seal. The 5-mm tube is then bent to the form of a small h. The ends of the tube are cut to the specified length and fire polished. The side arm is connected to a rubber bulb of convenient size by means of a short piece of rubber tubing containing a glass bead large enough to completely close the rubber tubing. A short piece of rubber tubing is used to attach the apparatus to the pipette. The size of the rubber bulb is, of course, determined by the volume of the pipette to be used. A ¼-oz bulb is convenient for pipettes up to 5 ml and a 1-oz bulb is satisfactory for pipettes up to 25 ml capacity.

The use of the apparatus is very simple. One first opens the glass bead valve by squeezing the rubber tubing around it and expels the air from the rubber bulb by squeezing. Release of the bead valve when the rubber bulb is collapsed produces a "portable vacuum supply." The tip of the pipette is then introduced under the surface of the liquid and the open top of the apparatus is closed with the finger tip. The pipette is filled by gently squeezing the glass bead valve. When

[1] This work was supported in part by funds received from the Eugene Higgins Trust through Harvard University.

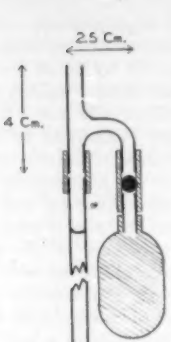

FIG. 1. Diagram of a simple and easily constructed pipette.

the liquid is drawn into the pipette to the desired level, the glass bead is again released. The meniscus is adjusted and the contents of the pipette delivered with finger tip control as with an ordinary pipette.

The apparatus described here does not fulfill the need for a truly remotely controlled pipette. It does, however, provide many advantages over the available types of safety pipettes. (*a*) It is simple in design and inexpensive. (*b*) One can accurately control the delivery of any desired volume of liquid by varying the size of pipettes and rubber bulbs employed. (*c*) Smaller pipettes may be filled several times with a single emptying of the rubber bulb. (*d*) With practice it is possible to accomplish the entire pipetting operation using only one hand.

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Local Refractometry of Cell Particulars with the Cylindrical Lens Microscope

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Cylindrical lens systems, as used preferably in electrophoresis equipments, permit the direct registration of local refractive differences within mobile protein fractions. This ingenious registration method, as described by Philpot (*1*), Svensson (*2*), Wiedemann (*3*), and others, is suitable not only in electrophoretic problems but likewise for studies on resting boundaries and refractive gradients within anatomical microscopic specimens. While by other refractometric methods only the optical properties of one structure point after the other can be measured, the Philpot-Svensson method directly shows the refractive gradients, i.e., the local changes of the product of refractive index × thickness, of the microscopic structures within a rectangular area of the sample and records it. Therefore, the one dimension is available for automatically plotting a diagram of the refractive gradient, and the other dimension is used as abscissa to show position in the object.

Generally, the usual Philpot-Svensson optics within an electrophoresis equipment reproduce an image of an area of 40–50 mm in height; in microelectrophoresis apparatuses the distance may be 10 times less, i.e., a few millimeters. For further biological studies it would be of value to increase the resolving power of the instrument or, accordingly, to minimize the structure particulars which can be analyzed by this method.

For such studies the use of a cylindrical lens microscope (Fig. 1) is recommended. In this instrument the image of the entrance slit (2) is projected onto a revolving slit (5) by means of a schlieren objective (3, 4). The microscopic specimen (7) is placed between the two symmetrical halves of the objective.

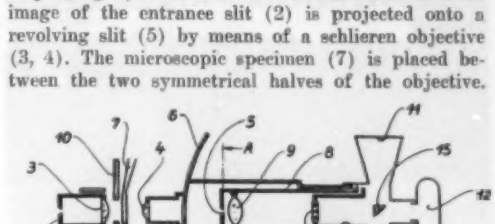

FIG. 1. Scheme of the cylindrical lens microscope.

A small area of the specimen, screened out mechanically, is projected by the lens (9) onto a focusing screen (11) by means of the prism (15) or immediately onto the film of a miniature camera (12). The oblique slit (5) is reproduced by the cylindrical lens (14) as a sharp, vertically arranged line seen as the base line in the final diagram, provided the microscopic specimen is optically empty. In this way each structure detail of the sample, based on differences of refractive gradients, leads to a lateral deviation from the above-mentioned baseline.

If a microscopic specimen is put into such a cylindrical lens system, a result is obtained such as that shown by Fig. 2. These schlieren graphs are taken from different, not fixed, and not stained tissue sections, cut at approximately 30 microns thickness. Each tissue has a relatively characteristic diagram. Homogeneous biological tissue gives relatively uniform diagrams. Complexly composed tissues such as human parenchymatous organs give more complicated graphs difficult to interpret. On the other hand, simple model tests, such as thin glass threads in one or more imbibition fluids, give simple graphs mathematically easy to explain (*4*). Keck (*5*) shows diagrams of skeletal muscle tissue of the isolated singular living muscle

[1] I am indebted to H. Engel of the University's Institute for General Botany for helpful suggestions.

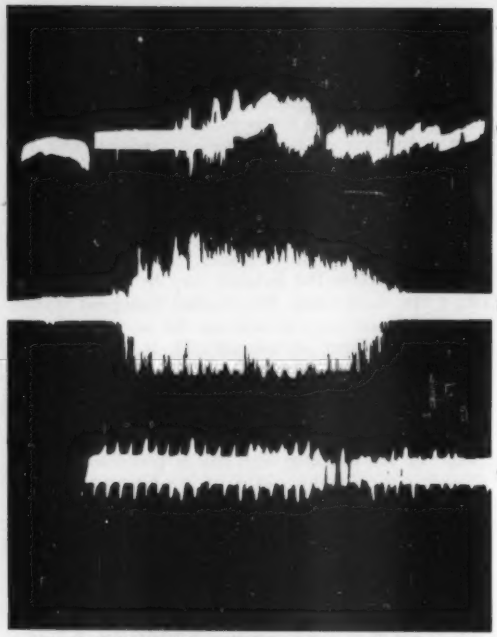

FIG. 2. Cylindrical lens diagrams representing the refractive gradients within a microscopic specimen: *a*, from a colloid-rich goiter; *b*, from skeletal muscle tissue; and *c*, from epithelium tissue of *Allium cepa*.

fiber and likewise of actomyosin obtained in the usual way.

Figure 3 shows the minimal range from which the author was able to take a self-plotting diagram of refractive gradients formed by cylindrical lens optics. The photomicrograph is taken with epithelium cells of *Allium cepa* after experimentally induced plasmolysis. The plasmolysis was carried out according to Cholodny and Sankewitsch (*6*) by short evacuation of small parts of the upper concave epidermis and by immersion of the epithelium cells into a 0.025 *M* potassium chloride solution for 24 hr. Then the tissue was brought into a 0.75 *M* solution of saccharose in 40 min. The rectangle drawn in the photomicrograph signifies the area from which the cylindrical lens measurement can be made. This area includes a part of only *one cell*. Within the cell two clots of the protoplast and a ghost of the nucleus are to be seen. The corresponding schlieren diagram of refractive gradients is given in the lower half of the photograph. Each detail of the cell structure corresponds to a part of the diagram.

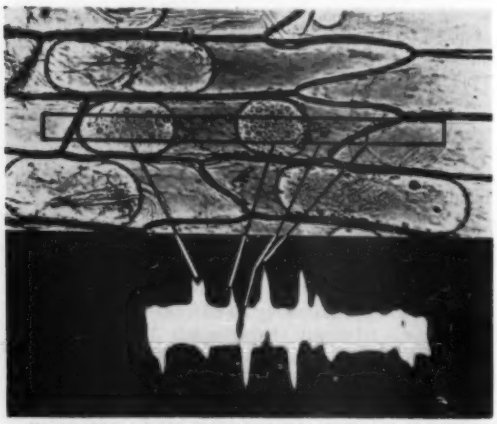

FIG. 3. Photomicrograph from epithelium cells of *Allium cepa* after experimentally induced plasmolysis. A part of one single cell is screened out. Below in the figure is the cylindrical lens diagram corresponding to the inserted rectangular area of the same cell as shown on the photomicrograph above.

This is the smallest area that, at present, can be screened for cylindrical lens measurements and analyzed for self-plotting one-dimensional refractometric studies by the usual Philpot-Svensson optics. The described method gives a more quantitative but less obvious result about local refractive gradients within a biological structure than colored phase contrast or schlieren methods, as published by Sailor-Brice-Zernike (*7*) and by the author (*8*).

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A Technique for Collecting, Mounting, and Sectioning Airborne Particulate Material

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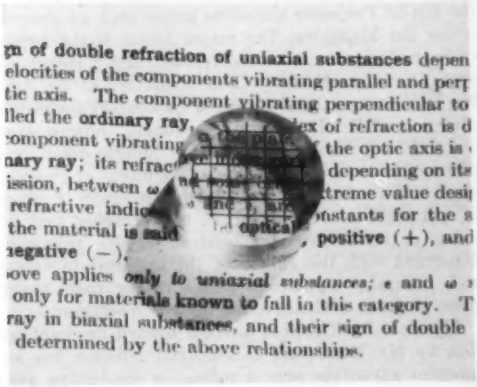
The collection and identification of airborne particulate material is an important part of many studies of the earth's atmosphere. One of the most convenient and efficient methods for collecting such material is by filtration. However, if filtration is employed, it has usually been necessary to remove the particles from the filters in order to identify the material collected. Such removal is tedious and is usually not quantitative.

Recently a technique has been developed in these laboratories for mounting and sectioning such particles without removing them from the filters. The filters are rendered transparent in the process, which greatly aids in determining the optical properties of the sectioned particles. The filters used are the cellulose acetate-cellulose nitrate filters developed by Goetz

(*1*) and now sold commercially under the trade name Millipore filters.[1] They filter mainly by a screening action whereby the particles are deposited on the filter surface. These filters become transparent when mounted in a medium having approximately the same refractive index as the filters (about 1.50).[2] Advantage is taken of this property by mounting the filters in methyl methacrylate. A filter on which particles have been collected is placed, collecting surface up, at the bottom of a hollow steel cylinder. Powdered methyl methacrylate is added and heated to about 150° C in a metallographic mounting press. A pressure of about 6000 psi is then applied and the plastic is allowed to cool to at least 80° C. The transparent cylinder of methyl methacrylate is then removed from the press.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...the material is said ... optical ..., **positive** (+), and
...**negative** (−).
...ove applies ***only to uniaxial substances;*** ε and ω
...only for materials known to fall in this category. T
...ray in biaxial substances, and their sign of double
...determined by the above relationships.

FIG. 1. Dust particles on a Millipore filter mounted at the surface of a cylinder of methyl methacrylate. Note that printing can be read on the page beneath the cylinder. The lines on the surface had been printed on the filter by the manufacturer. Original diameter of cylinder was 2.5 cm.

The now transparent filter and the particles collected on the filter are embedded in one end of the cylinder.

The filter portion is now ground away to the plane of the particles and grinding and polishing continued, using standard metallurgical techniques, until the particles are flat on one side. The plastic cylinder is then returned to the press, particle side up. A thick layer of powdered methyl methacrylate is placed on top of the particles, and the heating and pressing are repeated. Instead of reheating the plastic cylinder in the press, as described above, a second, particle-free, plastic cylinder can be prepared and cemented in place over the polished surfaces of the half-sectioned particles. The cement used is a solution of methyl methacrylate in chloroform. The particles now lie in a plane bisecting a cylinder which is about twice its original length. Most of the plastic is cut away[3] from the unpolished side of the particles. The particles are then ground and polished into thin sections. Most of the remaining plastic is sawed and ground away, leaving the particles mounted in a thin disk of methyl methacrylate. This disk is cemented to a microscope slide to complete the preparation. The particles are now in a form convenient to study with a petrographic microscope or with chemical microrgic techniques (*2, 3*).

Figure 1 shows dust particles on a Millipore filter mounted in the surface of a cylinder of methyl methacrylate. Printing can be read on the page beneath the cylinder. Figure 2 is a photomicrograph of dust particles collected on a Millipore filter and sectioned in plastic. A petrographic microscope was used and the anisotropic nature of several of the particles is apparent.

FIG. 2. Dust particles collected on a Millipore filter and sectioned in plastic. Transmitted illumination, crossed nicol prisms. 150 ×.

Various modifications of this technique are undoubtedly possible. Filters containing particles which would be altered by the heat and pressure of the molding process could probably be mounted by covering them with liquid monomers, or polymers, of the self-curing type.

[1] Lovell Chemical Co., Watertown, Mass.
[2] Daylight, room temperature.
[3] This can be done easily and accurately by means of a lathe.

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Manuscript received August 20, 1953.

Comments and Communications

Development of the ER-55 Projector[1]

MR. BEAN has described the ER-55 Projector so well, that there is practically nothing to be added. Still, I can say something that he did not because of the modesty of an inventor. This is an extraordinary development. I would say even revolutionary, if this term has not been abused by commercial advertising.

What is so extraordinary about this? Is it not just another scaled-up model of the Multiplex projector? Yes, it is! But, it has its own foundation and special features which required an insight, imagination and organizational daring.

All these qualities were needed to make the engineering and managerial decision that it would be a good gamble to design a Multiplex-type projector which would stand somewhere between the original Multiplex and its extremely ingenious modification designed by Kelsh.

There were two relatively easy ways to the solution of the design problem. If something in between seemed promising, the swinging light source, as used by Kelsh, could be adapted without major difficulties. The other approach could be to use a scaled-up Multiplex condenser. Mr. Bean rejected both available solutions because of good engineering reasons. He chose a third one, an entirely unexplored and unusual approach.

Some people may say that there is nothing unusual in utilizing an elliptical reflector as a condensing element. Correct! Elliptical reflectors have been used for a very long time, and one may add that off-axis aspherical reflectors, such as paraboloids, also have been used. But at least I do not know of any previous application of an off-axis ellipsoid as a condenser in a precision wide-angle system. Its incorporation in the illuminating system was a daring decision by the research and development section of the U. S. Geological Survey. This decision was made, so far as I know, despite some warnings by qualified optical men that the system may not produce satisfactory results. Even I, despite my curiosity for exploring the unknown, and my usual optimism, could not go in my discussions with Mr. Bean, any further than to say that, of course, the reflector will throw a large quantity of light on the diapositive, but this light would probably be distributed in zones which may not be tolerable. As we can detect now, there are some illumination zones in the projection plane. However, they are hardly perceptible in the image of the terrain. To me, a curious optical man, the most unfortunate fact is that these zones apparently originate from the optical imperfections of the glass of the bulb. I would like to break that bulb, just to see what the reflector does by itself.

With the excellent general background of this development, two minor critical remarks should not sound too discordant.

Mr. Bean said that it was obviously necessary to increase the size of the diapositive in order to obtain better resolution, and he referred to some computations substantiating this statement. I have not seen them, but I know that computations of this nature cannot be entirely reliable. The final proof should be in actual measurements. Quantitative data were not given in Mr. Bean's paper. This is a fault. However, I make this remark purely for its rhetorical value. Even without such data, we may expect that, provided a good optical system is used, the image produced by the ER-55 Projector should be better than we observe under the Multiplex. The major factor is the larger ultimate image scale of the former. Many recent investigations, particularly those conducted at the Boston University Optical Research Laboratory under the direction of Dr. Duncan E. Macdonald, indicate that many factors besides resolution of minute detail, are of importance for satisfactory recognition of images; among these factors, magnification occupies a place of prominence. It should not be forgotten that in using a photogrammetric system we are primarily concerned with the ability of the operator to detect and recognize significant detail rather than about some abstract evaluations of optical resolution.

My second criticism is directed toward the implication by Mr. Bean that an elliptical reflector has an inherent advantage over a refractive condensing system because the latter is afflicted with aberrations. Please be assured that the original Multiplex condenser is a system with an excellent correction of monochromatic aberrations, and that its chromatic aberrations have been reduced to an acceptable minimum. An elliptical reflector is inherently achromatic, but its monochromatic aberrations are not negligible when a source of substantial size is used.

Then why do we have more light with the ER-55 Projector? The answer is not simple. Forgetting some usual fallacies about condensing systems, the basic factors which determine the usable light in a projection system are: the magnification, the f-number, the transmittance losses, and the brightness of the source. The same source is used in both the standard Multiplex projector and in the ER-55. The product of the magnification and the f-number is the same for both. (The magnification of the U.S.G.S. Multiplex projector is 12, and its f-number is about 12; the magnification of the ER-55 is about 9, and its f-number is 16; the product is 144 for both.) The only factor that apparently can account for the difference in illumination is the different transmittance losses of the two systems. Another hidden factor may be in the possibility that the ER-55 utilizes a more favorable aspect of the source filament, with the resultant increase of the actual collected light. It would be an interesting project to investigate the theoretical and

[1] Based on a comment made at the 19th Annual Meeting, American Society of Photogrammetry, following an address by Russell K. Bean (see pp. 484–86 of this issue).

empirical causes of the increased amount of the projected light by the ER-55 Projector. And, of course, it would be highly desirable to have quantitative data.

Mr. Bean properly gave the credit to all those who participated in the development of this new unusual device. For historical interest, I may add that several years ago the possibility of utilizing an elliptical reflector was discussed with me by the members of the Engineer Research and Development Laboratories at Fort Belvoir, and that I was rather pessimistic about this idea. However, the Fort Belvoir project did not envision an off-axis ellipsoidal reflector such as Mr. Bean had in progress. As I understand, the project was never given sufficiently high priority and eventually was abandoned.

I may emphasize also the very excellent work done by the Corning Glass Company in overcoming the difficulties involved in producing a very satisfactory glass blank; by the Fecker Company in finishing the blank to an accuracy usually unobtainable for such products in ordinary manufacturing practice; and by the Silver Shop in producing replicas of excellent optical quality.

Summarizing, I may say that this is a new development which may become another milestone in the history of optics and of photogrammetric instruments.

35 Everett Street
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K. PESTRECOV

Received January 19, 1953.

A Scintillation Counter for the Measurement of Weak β Rays

RECENT publications (*1–4*) have emphasized the value of the liquid scintillator technique for the measurement of β rays in general, but more especially of those emitted by C^{14} and H^3 whose detection and counting was, up to now, a painstaking job. A description of the counter that we have been using for several months may be of interest to those attempting to systematize the method.

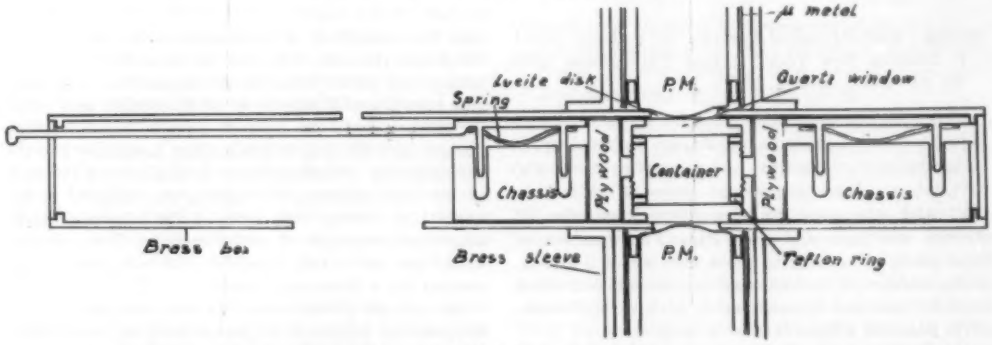

FIG. 1.

Our assembly (Fig. 1) consists essentially of a movable brass chassis in a light-tight brass box. The chassis is provided with a plywood receptacle into which a small cylindrical brass container with Pyrex or quartz faces can be fitted. In the off position one can either put the container into or remove it from the receptacle, while no light falls on the photomultiplier tubes. In the on position one finds the container between the sensitive areas of the tubes and, with proper electronic circuitry, gets only coincidence pulses from the system. The box is built in such a way as to permit adjustment of the space between the tubes.

We had to face three main problems: (*a*) Making a liquid-tight container, with due regard to the fact that it would hold powerful organic solvents; this difficulty was overcome with Teflon flat rings. (*b*) Getting good optical transmission from the container to the photocathodes; this was partly achieved by means of a lucite disk carved on one face to fit the tube head of the photomultiplier and stuck to it with Canada balsam. (*c*) Getting the proper chemicals which, to our knowledge, are produced neither in France nor in Germany; thus far we have used the rather inefficient α-naphthylamine dioxane mixture for the measurement of HTO samples with, however, encouraging results.

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Manuscript received February 9, 1953.

A Potential Hazard in Flame Photometry

THE necessity of a clean source of air or of adequate filtering to prevent cationic contamination of compressed air used in flame photometry has frequently been stressed. Recently we had an experience with a type of contamination that affects the operator rather than the results.

One day, shortly after the burner of our flame photometer was lighted, an acid odor, as of nitric or hydrochloric acid, began appearing in the room and one of the technicians developed a headache. No contamination of the instrument with acid could be found, and the odor continued even after thorough rinsing of the atomizer system. The effluent gas from the burner chimney rapidly produced the acid color on moistened indicator paper, and this effluent had a strong acid smell. The compressed air going to the instrument was noted to have a somewhat oily odor but none of the acid smell. When a change was made from the central air line to a small compressor in the room, the acid odor disappeared from the chimney and the effluent gas no longer caused a change of the color of the indicator paper. Consultation with the engineers regarding possible contamination of the air supply disclosed that nothing had been done to the air compressor or lines. However, on the day previous, during the search for a leak in the refrigeration equipment, some Freon-12 (CCl_2F_2) had been lost. Since this was in the same room with the air compressor and its intake, some of the Freon had entered the compressed air tank. This gas was decomposing in the burner of the flame photometer, liberating irritating gases such as HF, HCl, chlorine, and phosgene. When the central compressed air supply was vented outside for a time, a later test no longer showed it to produce acid. Thus, obviously care must be taken to prevent access of Freon or other halogenated hydrocarbons to the air supplied to gas burners, to avoid the formation of irritating toxic products.

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Received August 31, 1953.

Book Reviews

Modern Radiochemical Practice. G. B. Cook and J. F. Duncan. New York: Oxford Univ. Press, 1952. 407 pp. Illus. + plates. $8.50.

This book has been written for the purpose of providing a detailed guide to radiotracer methodology. It is directed toward students and research workers who have taken a beginning college course in radiochemistry and who have an elementary knowledge of nuclear structures and properties. For members of these groups who wish to learn more about the practical problems of methods and instrumentation which must be mastered for successful work in radiochemistry, this text will be extremely helpful.

Dr. Cook and Dr. Duncan have divided their text into seven chapters. The first chapter is an outline of the scope of radiochemistry and familiarizes the student with the principal operations involved in the separations of mixtures of radioisotopes, and with the many ways in which such isotopes are used in chemical investigations. The second chapter reviews, in considerable detail, the types of radiations emitted by radioisotopes, the laws of radioactive decay, and the methods used for determinations of energies and half lives. The third and fourth chapters describe the various types of equipment employed to measure radiation, their construction, operation, and advantages and disadvantages for a given type of radiation. Chapter five reviews the methods used for the production of radioisotopes (with particular attention to the very important nuclear reaction of slow-neutron capture), the choice of target material, calculations of yields, and the separation of radioelements by the Szilard-Chalmers reaction. Chapter six describes the techniques and errors involved in comparative and absolute counting of β activity in solids, liquids, and gases. In chapter seven the authors describe the laboratory designs and the health precautions necessary for the safe handling of radioisotopes. A final section (67 pp.) of the book presents 30 experiments designed to acquaint the student with some of the important techniques and concepts of radiochemistry. These experiments are very well designed and comprise a fine manual for a laboratory course.

An example of the authors' excellent presentation of the practical aspects of radiochemistry is the inclusion (in chaps. IV and V) of tables which show the common faults observed in the performances of Geiger counters, preamplifying units, scalers, and power packs. These tables list systematically the symptoms of, the possible causes of, and (most important) the remedies for these various faults.

The book is very readable, both from the standpoint of clarity of presentation and of the typography, and it is remarkably free from typographical errors. The only technical error noticed, and it is of small consequence, is that the value of E_{max} for C^{14} is given as 0.158 Mev on page 157 whereas on pages 222 and 254 it is given as 0.14 Mev. This book should be of considerable value to anyone interested in the subject of radiochemistry.

RICHARD M. LEMMON

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Chemical Process Machinery. 2nd ed. E. Raymond Riegel. New York: Reinhold, 1953. 735 pages. Illus. $12.50.

Chemical engineers and practicing chemists will welcome the appearance of the new edition of another text of Professor Riegel. This edition has brought the show window of chemical process equipment abreast of current development. Scores of drawings, photographs, and tables are generously given to make the description of machinery readily understandable. Throughout the book there are 597 figures and 92 tables.

New materials have been added in almost every class of process equipment in this edition. In the second chapter on "Devices for the Dry Reduction in Size of Solid Materials," two new crushers manufactured by Allis-Chalmers and a newly developed ball mill are presented. Numerous magnetic separators and related devices using permanent magnets instead of electromagnets are the new features in Chapter 3 on "Screening and Grading Equipment." Other equipment which has been included in subsequent chapters are: "Zipper," a closed belt conveyor; newly developed multisphere for gas storage under high pressure; several new chemical pumps; proportional feeder containing a Pitot tube; the Lapp Pulsafeeder; multiclone; P-A cyclonic scrubber and P-A Venturi scrubber; electromatic air filter; the string discharge rotary vacuum drum filter; drum suction filter of panel type; centrifugal filters; continuous operating separators and clarifiers; Conkey integral evaporator which is a long-tube evaporator with natural circulation and is a self-supporting type manufactured by General American Transportation Corp.; Conkey flat heating surface evaporators with the Rosenbled channel switching system; downflow, low-temperature evaporators suitable for handling fruit juices; turbo-drier of rotating shelves; bubble cap and tray construction; continuous crystallizer of Krystal System which also produces a classification of the crystals.

Entirely new treatment is devoted to the fundamentals of distillation and fractionation and the mixing of liquids. The materials included for the first itme are molecular distillation, absorption refrigeration, and new methods of measurements and automatic instrumentation. In the chapter on "Devices for Heating and Cooling," Riegel has given a comprehensive introduction to the application of atomic energy to the power generation.

Although descriptions of a few important pieces of processing machinery and notes regarding recent developments are missing in the book, it has fulfilled its purpose as a text of chemical process machinery and it gives a logical treatment from the standpoint of their application. The coverage is comprehensive and up to date. The book is recommended as a text to chemical engineering students. For practicing engineers and manufacturing chemists, the book should prove to be extremely useful in the selection of equipment for processing needs.

For a number of years the selection of a text in processing equipment for chemistry students who are minors in chemical engineering has been a difficult problem. The ordinary text in chemical engineering seems to be too quantitative to stimulate the interest of chemists who are not prepared for equipment design. A satisfactory solution is now provided by Riegel's book which, however, contains just enough numerical illustrations for more insight to the equipment.

In all chemical plants and most petroleum refineries, the most important piece of equipment is the reactor in which chemical reactions are taking place. The initial investment in a reactor usually accounts for a major percentage of the total cost of a plant. The performance of a reactor has been a day-to-day concern to chemical engineers supervising a plant. So far the descrpition of this important chemical processing equipment is missing in texts and books dealing with chemical processing equipment.

In congratulating Professor Riegel on his contribution, this reviewer would like to suggest the inclusion of chemical reactors in the next edition of *Chemical Process Machinery.*

JU CHIN CHU

Department of Chemical Engineering
Polytechnic Institute of Brooklyn

Speech and Hearing in Communication. 2nd ed. of *Speech and Hearing.* Bell Telephone Laboratories Series. Harvey Fletcher. New York–London: Van Nostrand, 1953. 461 pp. Illus. $9.75.

This is a highly authoritative and inclusive account of present-day knowledge of speech and hearing—with a little about language as well—in particular application to the operation of communications systems. Dr. Fletcher as a young man had something to do with measuring the charge of the electron, but after he joined the Bell Telephone System in 1916 his work turned to acoustics; he was an early president of the Acoustical Society of America. Since his retirement from the post of Acoustical Research Director of the Bell Telephone Laboratories he has returned to his native Utah to become Director of Scientific Research at Brigham Young University. He is heartily to be congratulated for having organized so well in this book, not only the massive results of 35 years of investigation by agencies of the American Telephone and Telegraph Company, but also the many essential contributions from other laboratories and writers. References to all this work abound, and there are both name and subject indices.

The book is recommended to students and teachers of speech, to audiologists and otologists concerned with hearing, as well as to communications engineers who deal with the multifarious applications of such information. It supplants Fletcher's first book on these subjects, which was published many years ago.

Communications engineers have to make their living out of tiny amounts of energy. "Joe took father's shoe

bench out." "She was waiting at my lawn." These two testing sentences contain all the fundamental sounds which contribute appreciably to the physical power of English speech. Spoken in ordinary tones by a typical voice they represent no more than 1000 ergs of energy in the sound waves. For comparison, a little 25-watt light bulb uses up energy at the rate of 2½ billion ergs every 10 seconds—so it would take the continuous chatter of 2½ million people to keep even. When speech must be transported by wire or radio to great distances the layman should not accept the matter so casually. (Too bad that so much of what people have to say is less wonderful than the machinery which permits them to say it.)

Chapter 14 entitled "Space-Time Pattern of Hearing" is especially significant. Fletcher presented this first in 1930, and now considers that "the experimental data that have accumulated since then indicate that the main parts of the theory are correct." He regards the observations of Békésy as having left "no doubt as to the general mechanical behavoir of the cochlea."

The book is handsomely printed, with many mathematical equations and diagrams.

JOHN Q. STEWART

Princeton University Observatory

The Science of Color. Committee on Colorimetry of the Optical Society of America. New York: Crowell, 1953. 385 pp. Illus. + plates. $7.00.

In 1922 a Committee on Colorimetry, under the chairmanship of Leonard T. Troland, published a report on colorimetry in the *Journal of the Optical Society of America and Review of Scientific Instruments.* That report defined a clear and consistent terminology in the field of colorimetry; summarized the available physical, psychophysical, and psychological data relating color to its stimulus conditions; and outlined the principal methods of color measurement. At the time of its publication, the 1922 report was the most complete and authoritative compilation of material in the field of colorimetry. It stood for years as the outstanding reference source on this subject.

Some years ago the Optical Society recognized that the 1922 report was in need of revision and, in 1933, a new committee, under the chairmanship of Loyd A. Jones, was appointed to revise the earlier work. This newer committee comprising 23 of the most distinguished names in color science, has been at work since 1933. The present volume represents the results of their efforts.

The Science of Color contains nine chapters: From the Art of Coloring to the Science of Color; The Concept of Color; Anatomy and Physiology of Color Vision; Psychological Concepts: Sensory Aspects of Color; Psychological Concepts: Perceptual and Affective Aspects of Color; Physical Concepts: Radiant Energy and Its Measurement; Psychophysics of Color; Quantitative Data and Methods for Colorimetry; and Colorimeters and Color Standards. There follow some 600 references and 22 pages of an unusual Glossary-Index. Terms are not only listed and indexed; they are also defined.

No review would be complete if it failed to mention the wealth of illustrative and tabular material in the book. There are 25 handsome color plates, over 100 black-and-white illustrations, and 40 tables. As in the 1922 report, the great amount of quantitative material presented in the tables and in some of the illustrations guarantees that this will be a standard reference on colorimetry for many years to come.

For all that, *The Science of Color* is likely to leave the expert a little disappointed in ways of varying importance, some small, some large. The first chapter, for example, devotes a considerable amount of space to some archeological findings and to the use of color in prehistoric and ancient art. This is all very interesting, but one wonders if the space should not have been more suitably devoted to a better coverage of quantitative data on the sensory aspects of color, or even to a fuller discussion of the scientific beginnings of the study of color (accorded a scant 4 pages of the 29 comprising the first chapter).

Then there is the matter of the references which, despite their impressive number, are limited in value because they are not indexed. At the very least, they might have been listed alphabetically by author.

One might go on and list a number of more minor annoyances, inaccuracies, and the like, but to do so might only be an indication of the reviewer's perfectionistic expectations. This is an outstanding book in the field of color. Of that there can be no doubt. If you work with color or want to study it scientifically, you cannot afford to miss it.

A. CHAPANIS

Bell Telephone Laboratories
Murray Hill, New Jersey

Scientific Book Register

Atomic Weapons in Land Combat. G. C. Reinhardt and W. R. Kintner. Harrisburg, Pa.: Military Service Pub., 1953. 182 pp. Illus. $3.95.

Tables of Normal Probability Functions. (Reissue of *Mathematical Table 14*, with corrections.) National Bureau of Standards Applied Mathematics Series 23, 1953. Prepared by New York Mathematical Tables Project. Order from Government Printing Office, Washington, D. C. 344 pp. $2.75.

Medical Schools in the United States at Mid-Century. John E. Deitrick and Robert C. Berson. New York–London: McGraw-Hill, 1953. 380 pp. Illus. $4.50.

The Green and Red Planet. A physiological study of the possibility of life on Mars. Hubertus Strughold with assistance of Green Peyton. Albuquerque: Univ. New Mexico Press, 1953. 107 pp. Illus. + plates. $4.00.

Mathematical Aspects of the Quantum Theory of Fields. (Pub. from N.Y.U. journal *Communications on Pure and Applied Mathematics*, 1952–53.) K. O. Friedrichs. New York–London: Interscience, 1953. 272 pp. $5.00.

Motivation and Morale in Industry. Morris S. Viteles. New York: Norton, 1953. 510 pp. Illus. $9.50.

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SCINTILLATION COUNTERS

By J. B. Birks, Rhodes University, South Africa. *Electronics and Waves Series.* 148 pages, $4.50

This is the second publication in the *Electronics and Waves Series,* sponsored in London by Pergamon Press, Ltd. The first book of its kind, it is a complete review of the most important and versatile instrument in modern nuclear research, and is of value to graduate students and research workers in nuclear physics, physical chemistry, organic chemistry, and medicine as well as of importance for many industrial, agricultural, biological, and other applications of radio-isotopes. All factors influencing the performance and use of scintillation counters are discussed in detail.

MAGNETIC AMPLIFIER CIRCUITS

By William A. Geyger, U. S. Naval Ordnance Laboratory, White Oak, Maryland. In press

A practical exposition of the fundamental principles, characteristics, and applications of magnetic amplifier circuits. Material is classified according to circuit functions. Develops logically the various kinds of basic and more complex circuit arrangements, with as much emphasis as feasible on experimentally observed phenomena. Extended mathematical considerations and cumbersome proofs are avoided. For the most part, descriptive and graphical methods are used to give a qualitative interpretation of the essential facts.

INTRODUCTION TO ELECTRON MICROSCOPY

By Cecil E. Hall, Massachusetts Institute of Technology. *International Series in Pure and Applied Physics.* 434 pages, $9.00

Here is a systematic treatment for courses on the theory and uses of the electron microscope. Subject matter includes an outline of elementary electron optical theory, discussions dealing with the construction and properties of electron lenses and electron microscopes, the interactions of electrons with matter, and the characteristics of electron images. The largest chapter contains detailed descriptions of techniques for the preparation of specimens.

INDEX

Massachusetts Institute of Technology *Radiation Laboratory Series*

Edited by Keith Henney, Editorial Director of *Electronics* and *Nucleonics.* 160 pages, $4.50

This invaluable index contains a complete guide to the entire series. But it is more, too, for it tells the whole story of the Radiation Laboratory. Karl T. Compton who led the Division of the National Defense Research Committee which established the Radiation Laboratory tells of its beginning and development. Lee A. DuBridge who was Director of the Radiation Laboratory includes a history of its organization, describing the activities and advancements, and a discussion of its functions which went much further than research. And Louis N. Ridenour, the Editor-in-Chief of the Series, discusses the whole preparation from the beginnings to publication.

ENGINEERING ELECTRONICS

By G. E. Happell and Wilfred M. Hesselberth, Purdue University. *McGraw-Hill Series in Electrical and Electronic Engineering.* 508 pages, $7.50

A text for beginning electronics, this book is aimed at those students who wish to specialize in communications, servomechanisms, electronics, and power. It combines a theoretical and practical treatment as background material for further detailed study or for engineering applications in the nonspecialized field.

PRINCIPLES OF NUMERICAL ANALYSIS

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HIGHER TRANSCENDENTAL FUNCTIONS, Volume II

By A. ERDELYI of the Bateman Project Staff, California Institute of Technology. In press

This is the second volume of a four-volume set being published in coordination with the California Institute of Technology. This volume contains chapters on Bessel functions and related functions, error functions, exponential, sine, cosine integral and related functions, parabolic cylinder functions, orthogonal polynomials, elliptic functions and integrals.

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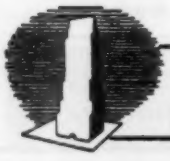

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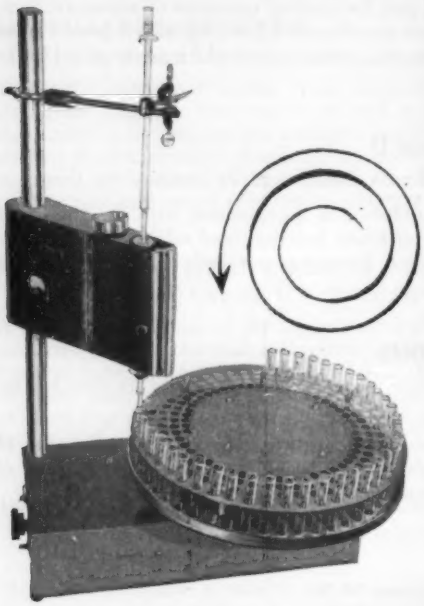

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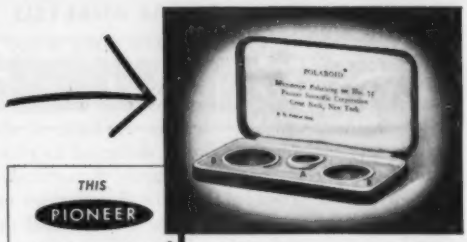

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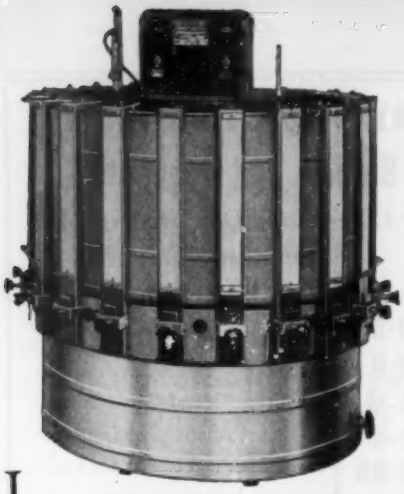

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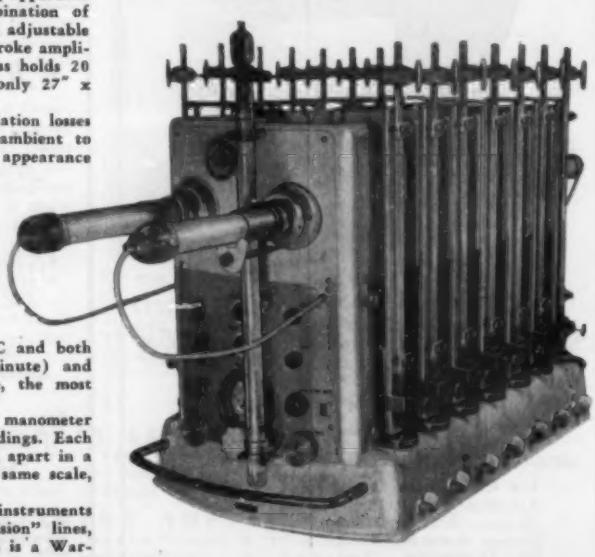

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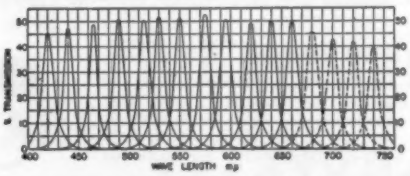

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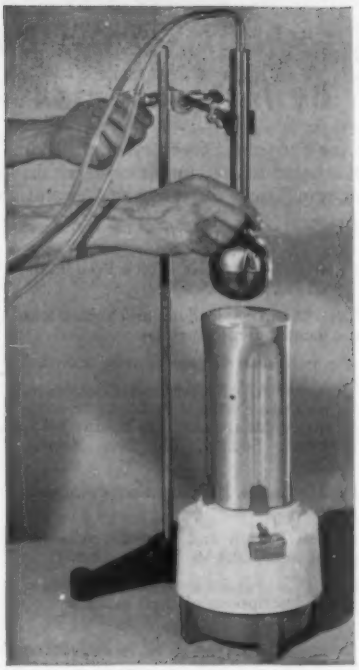

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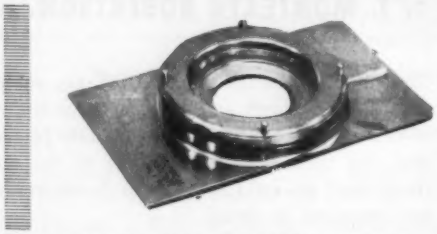

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Nov. 5–6. Pittsburgh Diffraction Conference (11th Annual). Pittsburgh, Pa.

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† Corcoran, A. C., et al., J. Lab. & Clin. Med. **32**, 60-67 (1953)
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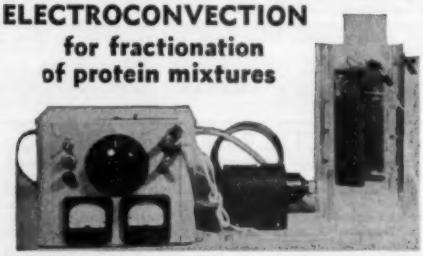

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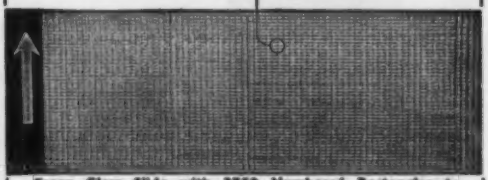

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